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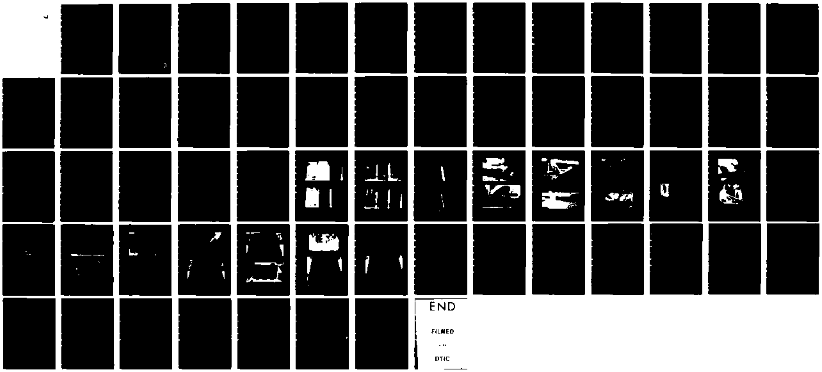

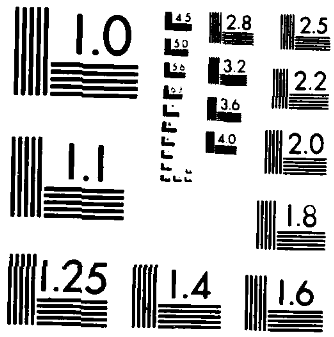

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TITLE: PRELIMINARY GUIDELINES FOR MAINTENANCE OF POLYURETHANE FOAM (PUF) ROOFING SYSTEMS

AUTHOR: R. L. Alumbaugh, S. R. Conklin, and D. A. Zarate

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NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

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METRIC CONVERSION FACTORS

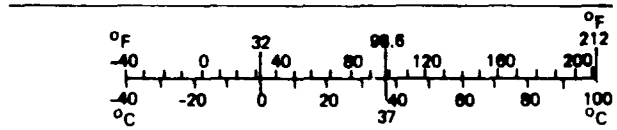
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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This report presents details of experiments and preliminary guidelines for maintaining sprayed polyurethane foam (PUF) roofing systems, which have been used in increasing numbers in recent years by government and the private sector. Many of these PUF roofs are now requiring maintenance because of improper materials, improper application, or length of time in service (age). Standard methods and procedures for

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20. Continued

maintaining and repairing PUF roofs have not yet been developed or used by manufacturers or contractors to any great extent. In general, each contractor has his own special maintenance procedures. A number of experiments have been conducted by NCEL in an investigation to establish effective procedures for maintenance of PUF roofing systems.

Library Card

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This report presents details of experiments and preliminary guidelines for maintaining sprayed polyurethane foam (PUF) roofing systems, which have been used in increasing numbers in recent years by government and the private sector. Many of these PUF roofs are now requiring maintenance because of improper materials, improper application, or length of time in service (age). Standard methods and procedures for maintaining and repairing PUF roofs have not yet been developed or used by manufacturers or contractors to any great extent. In generai, each contractor has his own special maintenance procedures. A number of experiments have been conducted by NCEL in an investigation to establish effective procedures for maintenance of PUF roofing systems.

CONTENTS

INTRODUCTION

Polyurethane foam (PUF) roofing systems have been used more frequently over the past decade, not only in the private sector but also at Naval shore bases. However, as with any new material, problems have occurred. When these roofing systems were first introduced, mistakes were made in their specification and application. Frequently, the roofs were installed and forgotten (i.e., there was no inspection and preventive maintenance program). Both of these factors led to many problems and a consequent high rate of failure.

PUF degrades when exposed to sunlight and must be protected by a suitable elastomeric coating system. If the elastomeric coating is applied too thin, is subjected to excessive mechanical damage, or has weathered excessively, it tends to spall or flake from the substrate, exposing the foam. When this happens, the surface must be recoated as soon as possible. If this is not done, the roofing system deteriorates and eventually fails as a result of ultraviolet (UV) degradation and water absorption into the degraded foam.

At some point in time, generally 6 to 12 years after application, the elastomeric coating systems will weather (age) to the point where maintenance is required to provide continued protection to the foam. When properly applied and protected, PUF should perform its required function as a roofing system for a minimum of 20 years. With the high-quality elastomeric coating systems that are currently available, it should be possible to obtain 20 years of service with only one recoating. Even higher quality coating systems are under development, and it is anticipated that some of these may perform well for the entire 20-year period. These life expectancies are predicated on an annual inspection and preventive maintenance schedule during which minor repairs are made. Without annual preventive maintenance, it is anticipated that the normal PUF elastomeric coating systems will perform for 6 to 10 years. With annual preventive maintenance, the life expectancy should be 8 to 12 years before recoating is required.

While there are numerous procedures and materials currently available for maintaining built-up roofing (BUR) systems, there are no standardized procedures for maintaining PUF roofing systems. The actual procedures employed are determined by the knowledge and ingenuity of the individual contractor. The objective of this research is to (1) investigate existing maintenance procedures for PUF roofs; (2) develop new maintenance procedures, materials, and methods for PUF roofs; and (3) standardize the best procedures for Navy use. This report summarizes the research that was carried out on maintenance of PUF roofing systems and provides preliminary guidelines (see Appendix) for properly maintaining these roofing systems.

BACKGROUND

Over the past 15 to 20 years, maintenance of roofs and roofing systems has become an ever-increasing problem. The problem with BUR systems has been compounded by changes in the composition of bitumen and felts, by material shortages, by poor workmanship, and by other factors that lead to poor performance and short service life of these waterproofing systems. This problem was emphasized by an Air Force report that BUR systems designed for a 20-year life are performing an average of 12 years (Ref 1). According to the National Bureau of Standards (NBS), about 15% of BUR systems fail within 5 years after construction, and indications are that within the Department of Defense (DOD) the rate of failure is even higher. Part of the shortened service life must be attributed to a lack of proper maintenance procedures and funding for roof maintenance programs. The best information available indicates that the annual maintenance cost for roofs at Naval shore activities is over $25 million.

Because of the increasing seriousness of the roof maintenance problem, the Naval Civil Engineering Laboratory (NCEL) was tasked by the Naval Facilities Engineering Command (NAVFAC) to investigate roofing systems under YF54.593.011.01.001, "Investigation of Roofing Systems for Maintenance of Naval Shore Structures." (The work is currently being conducted under Y0995-01-004-610, "Roofing Inspection and Maintenance.") This research was to be directed toward all areas of roofing problems. The objective of the investigation was to provide a significant reduction in maintenance costs for roofing systems at Naval shore bases by defining existing problems and identifying conventional and new materials and methods that might eliminate or alleviate these problems. An extensive survey of Naval shore bases was conducted in different climatic areas to define and delineate the most recent roofing problems (Ref 2).

The experimental program was to cover a broad spectrum of roofing problem areas that were either known or would be delineated by the roofing survey. In pursuing this aspect of the program, funds were provided to NBS to provide a state-of-the-art report on the effect of moisture on BUR (Ref 3). In addition to this contractual effort, support was also provided to the U.S. Bureau of Reclamation (USBR) Research Laboratories to aid in the preparation of a report on an extensive research effort that USBR had conducted earlier on new roofing systems (Ref 4).

Early in the NCEL roofing research program, NAVFAC requested that the Laboratory cooperate with the Northern Division of NAVFAC (NORTHNAVFAC) to develop and carry out an experimental field investigation of spray-applied PUF roofing systems at the Naval Reserve Center (NRC), Clifton, N.J. Reports of that investigation are presented in References 5 and 6. Because of the requirement to assist in the development of plans for the experimental field investigations of PUF roofing systems at NRC Clifton, the original experimental roofing investigations at NCEL were directed toward: (1) PUF roofing materials, and (2) coatings for protecting the PUF from weathering. This resulted in an interim report describing experimental weathering and laboratory studies of these relatively new roofing materials (Ref 7).

Since this initial work, much has been learned about these materials, their proper specification, and proper application. The industry has advanced, and much needed guidance is available to provide background information on materials and procedures necessary to obtain a good, long-lasting foam roofing system. Current guidelines for the design, specification, and installation of PUF roofing systems are available in NCEL publications (Ref 8 and 9) and Urethane Foam Contractors Association (UFCA) publications (Ref 10). These guidelines can be used until Navy Facility Guide Specification NFGS-07545, "Sprayed Polyurethane Foam for Roofing Systems" (pending), is issued. Navy Type Specification TS-07540 covers the use of silicone rubber coatings for protecting PUF. This type specification is scheduled for revision and updating in the near future and should also include catalyzed urethane coatings. As a result of NCEL's experience with PUF roofing systems, the initial maintenance effort was directed toward these unique materials.

SCOPE OF WORK

A study of roof maintenance procedures used by contractors indicated that the most frequently used method of foam repair is to broom the coated PUF roof, air blow* to remove dirt and deteriorated coating, and recoat with a suitable coating. This procedure involves the least amount of effort and is the least expensive. Brooming is frequently a satisfactory maintenance procedure as long as a large percentage of the existing coating is intact and little, if any, degraded foam is exposed. A more radical procedure consists of complete removal and reapplication of the PUF roofing system. This is only necessary when the existing PUF is so badly degraded that it no longer serves its proper function as a roofing system.

In between these two extremes, there are several other possible procedures. Procedures investigated in this study include the following:

1. Broom the existing surface and recoat with a suitable elastomeric coating system. This is a minimum procedure.

2. Broom the existing surface, prime, and recoat with a suitable elastomeric coating system. Priming may be required to provide proper bonding of the elastomeric coating or to stabilize a weathered foam surface.

3. Broom the existing surface, apply a new lift of foam, and coat with a suitable elastomeric coating system (as with a new foam roof).

4. Broom the existing surface, prime, apply a new lift of foam, and coat with a suitable coating system. Priming may be required to obtain a good bond between the foam and the existing roof surface.

5. Shave or sand the existing surface to remove bad coating and foam (until only good-quality foam remains). Blow off or vacuum all dust, and coat with a suitable elastomeric coating system or prime and

*Whenever the foamed roof surface is broomed, any loose residual dirt is blown off with compressed air that is free of oil and water.

coat with a suitable coating system. Priming may be required to obtain proper bonding of coating to foam or to stabilize the sanded foam surface.

6. Shave or sand the existing surface to remove bad coating and foam (until only good-quality foam remains). Blow off or vacuum all dust, apply a new lift of foam, and coat with a suitable elastomeric coating system, or prime, apply a new lift of foam, and coat with a suitable elastomeric coating system. Priming may be required to provide a better bond between the new foam and the sanded foam surface or to encapsulate any remaining dust.

All of these procedures were investigated to disclose their limitations and to determine which are most effective under different prevailing roof conditions. It is expected that the choice of maintenance method for any given roof will be dictated by the condition on that particular roof at the time. At times, two or more methods might be required on a roof to obtain the most effective results.

In addition to the maintenance procedures mentioned above, localized roof repairs may be required. For instance, small areas up to 10 ft^2 of poor-quality or water-saturated foam may need replacement. This type of repair is easily accomplished by removing the bad foam and replacing it with new foam applied either by a foam spray unit or by using single- or two-package "canned" foam units.

Annual preventive maintenance procedures should extend the effective life of PUF roofs. Techniques and materials for performing this annual maintenance are included in this investigation. Finally, some of the elastomeric coatings used on foam may present special problems when they require recoating; this aspect was investigated.

EXPERIMENTAL INVESTIGATIONS

Research directed toward development or selection of optimum maintenance methods for PUF roofing systems was conducted both in the laboratory and in the field. To provide weathered PUF roof test panels on which to perform experiments, 1-1/2 inches of Witco SS-0125A/SS-0126B foam (3-pcf density) was spray-applied to eight 4- by 8-foot sheets of 1/2-inch plywood. The foam was coated with one of the following materials:

- TT-P-95, Type 1, a rigid chlorinated rubber coating normally used for exterior concrete and masonry (three panels)

- TT-P-19, an acrylic latex coating normally used for exterior wood or masonry (two panels)

- TT-P-29, a latex coating for interior surfaces (three panels)

These particular coatings were selected because they had been used unsuccessfully on PUF roofs at several Naval activities before it was recognized that elastomeric coatings are required to accommodate the large expansions and contractions experienced by PUF roofs. The rigid coatings applied over PUF roofs at field activities had failed from 6 months to 2 years after application. The eight panels coated with the three systems listed above were placed on outdoor exposure racks at NCEL's experimental weathering site at the Naval Weapons Center (NWC), China Lake, Calif.*

Unfortunately, these coating systems performed better on the 4- by 8-foot test panels than on roofs at the other locations. After 19 months of field exposure, only three of the eight panels (TT-P-95 coated) had deteriorated sufficiently to be included in the maintenance research study at that time. The other five panels were transferred to the NCEL marine weathering site at Port Hueneme, Calif. Since the research could not be delayed until the 4- by 8-foot panels were ready, another approach was taken and the work was divided into five phases as shown below.

Phase 1 - Maintenance of Four Failed Test Panels of PUF Systems Taken From Each of Three Experimental Sites (12 Panels Total)

In order to proceed with the initial investigation as soon as possible, it was decided to utilize PUF roofing system panels that were included in another portion of the NCEL roof research program. Four of the systems described in Reference 2 and exposed at each of the three NCEL experimental weathering sites had either failed or were nearing failure after varying periods of exposure. These 12 systems and their conditions are listed in Table 1 and shown in Figures 1a, 1b, 1c, and 1d. A study of these figures shows that the condition of the systems varied considerably, due both to the different generic types and to the particular exposure site at which the systems were exposed. However, all 12 systems were considered to be in need of maintenance and were used in the investigation. The variation in the sample condition aided the study in permitting the use of several of the procedures listed under the SCOPE OF WORK section.

As with many other systems, proper surface preparation is the most important consideration in the maintenance of PUF roofing systems. If a deteriorated PUF roof surface is improperly prepared, it is highly unlikely that any maintenance procedure will be effective. As noted in the SCOPE OF WORK section, many different procedures for cleaning the PUF coating or otherwise preparing the PUF roof surface are included in the investigation in order to determine their relative effectiveness. These procedures involve tools or equipment for brooming, shaving, and sanding a degraded PUF roof surface. The different types of brooming equipment included in the overall investigation are shown in Figure 2. All of these except the long-bristled, heavy-duty push broom were used

*NCEL has experimental weathering sites at the following locations: (1) NCEL (marine weather); (2) NWC, China Lake, Calif. (desert site); and (3) Marine Corps Mountain Warfare Training Center (MCMWTC), Pickel Meadows, Calif. (cold weather site).

in the Phase 1 brooming operations. The equipment investigated for sanding and shaving is shown in Figures 3a and 3b. The sander is a heavy-duty, electrical disk sander, while the shaver is a 24-inch foam plane manufactured by Gusmer Corporation for shaving foam applied between studs in a wall. A similar piece of equipment, Quick Plane 2116, manufactured by Grand Rapids Scarfer Company, has recently been received and will be tested in the near future. The only other known equipment marketed specifically for shaving or preparing deteriorated PUF roofing surfaces is also marketed by the Grand Rapids Scarfer Company. This heavy-duty piece of equipment may be too heavy for use on many conventional roof decks.

The procedures and materials used for maintaining the 12 deteriorated systems and their new system numbers are given in Table 2. The reconditioned PUF roofing systems were coated or recoated with a two-component (catalyzed) urethane elastomer applied in two coats. Bo the black base coat and the oyster white topcoat were applied at the e of 1-1/2 gal/100 ft^2 to give an estimated total dry film thickness 30 mils.

The experimentally maintained PUF panels of Phase 1 have be exposed at the Port Hueneme site for about 5 years. Photomacrog p of the maintained surfaces were taken initially and periodically as systems weathered until the samples mentioned below were cut. Only one panel of each of the systems was prepared and exposed initially. Because of this, samples were not cut from these specimens for adhesion testing until they had been exposed for about 2 years, and approximately on an annual basis thereafter. The performance of each of the treatments was also rated, generally on an annual basis. After 4 years of weathering, additional small samples were cut from samples 7F-1 and 8F-1. During the maintenance procedure both were sanded to good-quality bare foam, 8F-1 was primed, and both were then refoamed. These samples were taken to determine if use of a primer improved the bonding character of the new foam to the old foam.

Phase 2 - Maintenance of 12 Coated and 8 Uncoated PUF Test Panels

Each of the three 4- by 8-foot foamed panels coated with TT-P-95 were cut into four equal sizes of 2 by 4 feet. The TT-P-95 showed mudcracking, crazing, flaking, and line cracking. In addition, foam had been spray-applied to eight 2- by 4-foot plywood panels that had been allowed to weather uncoated until the foam surfaces had degraded. These eight uncoated panels were used in surface preparation studies involving sanding. In all, 20 test panels were used.

All six of the experimental maintenance procedures were included in this phase of the investigation. The procedures, equipment, and materials employed in this phase are listed in Table 3 for each of the maintained PUF systems. The coating system used with this group of panels was Diathon, an acrylic latex elastomer applied in two coats at 1-1/2 gal/100 ft^2/coat (30 mils wet film thickness per coat). The degraded surfaces (TT-P-95) of syst ms 9F-1,2 and 10F-1,2 were thoroughly broomed with a rattan push broom (Federal Specification H-B-71). The surfaces (TT-P-95) of systems 11F-1,2 through 14F-1,2 were brushed with the two hand brushes (such as a GI brush) shown in Figure 2 to determine the relative cleaning effectiveness of brooming and brushing. The degraded uncoated foam surfaces of systems 15F-1,2 through 18F-1,2 were sanded with a heavy-duty disk sander to remove all degraded material, exposing a good-quality sanded foam surface. Following the surface conditioning, all loose foam material and dust were removed by blowing the surface with an air hose. Duplicate panels of each of the maintenance systems were prepared for Phase 2, and all panels have been exposed at the Port Hueneme site for about 4 years. A small section of each of the duplicate panels was removed periodically and returned to the laboratory to determine performance characteristics. Physical properties, such as coating and foam adhesion over unprimed and primed surfaces, were determined annually. These characteristics are described in Reference 7. In addition, photomacrographs were taken initially and at 6- to 12-month intervals as the systems weathered, and the systems were inspected and rated annually.

Phase 3 - Maintenance of Family Housing Roofs at the Naval Air Station (NAS), Lemoore, Calif.

NAS Lemoore, Calif., had foamed the roofs of about 108 of their family housing units in the late 1960s. These were flat-roofed units that had built-up roof (BUR) systems that were leaking. Since the roof decks were nearly level, the gravel was removed from the BUR and a course of lightweight concrete was added to provide slope. The roofs were then foamed with 3/4 to 1 inch of 2-lb/ft^3 density foam and coated. The housing unit roofs were foamed in two different groups, with a different coating system used in each group. One of these coatings was an aluminum asphalt; records were not available to determine the generic type of the second coating system. In any event, it did not appear to be elastomeric.

Considering that these roofs were 7 to 8 years old when inspected by NCEL personnel in 1977, the coated foam was in relatively good condition overall. The coating had spalled from the foam in a number of small areas on each housing unit roof, permitting the foam to degrade. However, degradation was limited to the surface of the foam and had not progressed to any appreciable depth into the foam. Scraping the degraded foam with a knife blade uncovered good-quality foam a short distance beneath the surface. In addition, a number of small blisters approximately 4 to 6 inches in diameter were evident between lifts on many of the roofs. The blisters were probably caused by perspiration dropping from the foam applicators on one lift of foam as the next lift was being applied.

Station personnel did not want to remove the old foam because this operation might affect the integrity of the lightweight concrete. As a result it was recommended that degraded coating and foam be removed by shaving or sanding, the exposed foam surface primed, and 1-1/2 inches of new foam applied and protected with an acceptable elastomeric coating system with granules. The contract specifications were prepared according to this recommendation.

The roofs were refurbished in the fall of 1977 in accordance with the contract specifications mentioned above. The degraded foam and coating on most of the roofs were removed with a heavy-duty disk sander (see Figure 4). The blisters mentioned above were removed in a similar manner. With the remainder of the roofs, the sanding disks tended to clog when removing the coating. As a result, it was necessary to use a BUR spudding machine to remove the coating and a small amount of the foam. Since this left a very rough surface, the remaining foam was sanded lightly to give a surface similar to that obtained when disk sanding only was used.

After the sanding was completed, all loose foam and dust were blown from the roof with an air hose, and the existing foam was given a tiecoat of hydrocarbon primer used principally to assure good bonding between old and new foam. Following the priming, an additional 1-1/2 inches of new foam (3-lb/ft^3 density) was applied (Figure 5). Then a catalyzed urethane was applied in three coats, with each coat applied at the rate of 1 gal/100 ft^2. Mineral roofing granules were broadcast into the wet topcoat at the rate of 50 lb/100 ft^2. The dry film thickness of the coating was approximately 30 mils. An overview of a finished roof is shown in Figure 6.

As the work at NAS Lemoore progressed, an attempt was made to incorporate several of the six NCEL maintenance procedures into the program. Procedure No. 6 (i.e., sand, prime, foam, and coat) was being used on most of the housing units by the contractor. However, by the time the contractor had agreed to try some of the other procedures, there were only two roofs left to complete. As a result, only procedure No. 6 was included. In general, the work progressed well, resulting in satisfactorily maintained roofing systems.

Phase 4 - Test and Evaluation of Repair Methods for Small Areas of PUF Systems at the Naval Reserve Center (NRC), Clifton, N.J., and NCEL Test Sites

The first three phases of the investigation described above were directed toward maintenance of the entire deteriorating PUF roofing system. Many times only small areas of a foam roof (i.e., 1 to 10 ft^2) require maintenance. These usually occur when there is some deficiency in the quality of the foam caused by: (1) the two components of the foam being off ratio when dispensed, (2) the foam sustaining mechanical damage following application, or (3) the foam becoming wet. In such cases, it is generally necessary to remove the affected foam down to the roof deck, refoam, and coat the newly foamed patch. When PUF spray equipment is available, patching of small areas presents few problems. However, if proper equipment and trained personnel are not available, other procedures must be used. This phase of the investigation was directed toward the small patch repair.

As noted above, with foam spray equipment and experienced personnel, patching repairs are simple and easy. Such repairs are described in Reference 5, where approximately 15 to 20 ft^2 of spongy foam was removed from the test roofs at NRC Clifton, N.J., replaced with new foam, and coated. This provided a monolithic roofing system that would perform the same as a new roofing system.

The patching investigation on the test roofs at Clifton, N.J., was initiated for two reasons. First, as noted in Reference 5, birds had removed from 1-1/2 to 2 ft^2 of foam from beneath the coating near the gravel stops. Second, it was necessary to remove samples of 1 ft^2 of foam from each of the five PUF roofing systems at the Clifton site to determine the insulating characteristics of the foam after weathering for 5 years.

When PUF spray equipment is not available, other sources of PUF, such as canned foam or foam boardstock, must be used. Canned foam is available in two forms: (1) single-component (one can), where the foam reacts with atmospheric moisture to cure; and (2) two-component (two cans), in which the components react to cure. The single-component foam must cure about 24 hours before it can be sanded. The two-component foam is sufficiently well cured in 1 to 2 hours to enable it to be sanded.

There are a number of single-component foams available in conventional spray can containers. Two of these were included in this investigation: (1) UFC Handi-Foam, manufactured by United Foam Corporation, Compton, Calif.; and (2) Polycel One, manufactured by Coplanar Corporation, Oakland, Calif. There are only two two-component foam materials known to NCEL. These are Froth-Pak, manufactured by Insta-Foam Products, Inc., Joliette, Ill.; and Versifoam, manufactured by Universal Foam Systems, Cudahy, Wis. The Froth-Paks were included in the investigation. The two-component foam is available in three different container sizes, the smallest of which is the conventional paint spray can (approximately 12 fluid ounces). The two cans each have a plastic tube that is connected into a plastic nozzle. When the trigger on the Froth-Pak is activated, the two liquid components meet and are mixed as they pass through and are dispensed from a special plastic mixing nozzle. Both the single- and two-component foams extrude from the cans as a froth (like shaving cream). The foams then expand about 50% as they cure. Plastic nozzles are available for spraying as well as for frothing.

Both single- and two-component canned foams were investigated at the NRC Clifton test site. Additional tests were conducted at NCEL in areas where PUF samples were removed for thermal conductivity measurements. The NCEL tests involved the two-component canned foam and either PUF or styrofoam insulation board that was cut to the approximate size of the foam removed from the roof. The shaped boardstock was then set into four or five beads of caulking material that had been applied to the roof deck, the area between the boardstock and the adjacent foam was caulked, and the surface of the foam was protected with a proper caulking material or coating. The use of both canned foam and foam insulation boardstock for patching is shown in Figure 7.

Phase 5 - Maintenance of Aged PUF System Test Panels Taken From NWC China Lake and MCMWTC Pickel Meadows, Calif., Test Sites

Concern has been expressed in the industry that the silicone coatings are difficult to recoat when it is necessary to maintain this type of coated PUF roofing system (i.e., the new silicone coating does not adhere well to the old silicone coating). To determine the validity of this concern, two 2- by 4-foot experimental panels that had been coated with a single-component moisture-cured silicone were returned to NCEL for an additional maintenance operation. One of these panels had been exposed at the NCEL experimental weathering site at NWC China Lake, Calif., while the second had been exposed at another NCEL site at MCMWTC Pickel Meadows, Calif. These two systems had been exposed for 8 years at these two sites and were in excellent condition. The only deterioration noted was very light checking of the silicone (1/8 to 1/4 inch in length) that occurred in the bottom of the valleys of the surface texture of the coating. This checking had occurred when the coating was first applied and had not progressed or changed in nature on weathering. The checking did not penetrate through the coating into the foam.

The two panels were each divided in half, and four different surface treatments were tried, one on each half of the panel, prior to recoating the surface with new silicone coating. These surface treatments included:

Panel 1.

System 19F-1 - The surface of the existing weathered silicone was thoroughly broomed (as might be done with power brooming) to remove all adhered dirt from the silicone.

System 19F-2 - The surface of the weathered silicone was thoroughly broomed while washing with water to remove all adhered dirt. The surface was then washed with clean water and allowed to dry completely.

Panel 2.

System 20F-1 - The surface of the weathered silicone was washed with a pressure water spray (approximately 170 psi) to remove adhered dirt and allowed to dry completely.

System 20F-2 - The surface of the weathered silicone was washed and scrubbed with water and trisodium phosphate (TSP) detergent, washed with clean water, and allowed to dry completely.

The cleaning operations all gave good clean surfaces. However, the panel that was washed with TSP appeared to be the cleanest. The cleaned, dry surfaces were then topcoated with two coats of moisture-cured silicone applied by spray at the rate of 1 gal/100 ft^2/coat. Small samples were cut from these panels to determine the adhesion of the new coating to the old coating before the systems were exposed and after 6 months of weathering at the Port Hueneme experimental weathering site.

RESULTS AND DISCUSSION

Interim results on these maintenance studies after a little over 2 years of weathering on the PUF maintenance panels were presented in Reference 11. Reference 11 also presented interim procedures for maintaining foam that could be used pending additional investigation. This current report presents results of a 5-year laboratory and small-scale field study along with preliminary guidelines for maintaining foam roofs (see the Appendix). These preliminary guidelines will become recommended criteria following their use in full-scale field maintenance operations. Each phase of the investigation is described below.

Phase 1

As noted earlier in the report, the condition of the 12 weathered systems used in this phase varied. For all practical purposes, no two systems were in the same condition. Because of this, it was not possible to have duplicates as in Phase 2; only qualitative information was obtained from this series for the first 28 months. Thereafter, small samples were cut from each of the panels for the adhesion tests mentioned earlier. Results of the inspection of these systems for performance during the 5 years of weathering are given in Table 4.

The three methods used in this phase for preparation of the surfaces were brooming, sanding, and shaving. All 12 panels were first broomed to determine the effectiveness of this technique. This treatment was relatively effective only on system 1F-1. It was also the only treatment used on systems 1F-2 and 2F-1. This was done because the authors have seen PUF roofs with this degree of deterioration merely broomed and coated, and wanted to determine if this was a satisfactory treatment. Figures 8 and 9 show system 1F-2 after brooming and coating, respectively. As noted in Table 4, brooming is not an effective treatment for surfaces that have a moderate percentage of flaked coating.

System 1F-1 did not have as much of the original urethane coating spalled from the foam as systems 1F-2 and 2F-1. As a result, system 1F-1 was performing better than the other two and was rated as good; system 1F-2 (see Figure 10a and b) was rated as failed and system 2F-1 was rated poor, respectively, after 5 years of exposure. System 1F-2 had absorbed water after 1 year of exposure. The slightly better performance of system 2F-1 (see Figure 10c) over system 1F-2 (Figure 10b) is attributed in part to the use of a primer, which improves the adhesion of the new coating to the old coating (compare adhesive properties for systems 2F-1 and 1F-2 in Table 5).

Where the old coating was mostly intact, as with system 1F-1, brooming was found to be an effective surface preparation. On the remaining nine panels of Phase 1, brooming was found to be ineffective because deterioration of the coating and foam surfaces was too advanced. Attempts were made to use the foam plane on these panels, but it did not have sufficient cutting ability to remove these coatings, particularly the moisture-cured urethanes. Even though some of these coatings were badly deteriorated, the remaining portion was still quite rubbery and tough. Only the disk sander was able to remove deteriorated PUF roofing systems; it was also used to partially sand the most deteriorated portions of systems 3F-1, 3F-2, 3F-3, 4F-1, and 4F-2. While the disk sander did a relatively good job, it is not effective in removing deteriorated rubberlike coatings, such as moisture-cured urethanes. A new, more rugged foam planer that may be more effective has recently been received and will be evaluated in the near future. This unit has a much heavier blade than the one that was tested.

After 5 years of weathering, systems 3F-1 and 3F-2 were providing good to very good protection to the PUF panels. Less than 10% of the old weathered coating had spalled before this maintenance was performed. Where there were breaks in the original coating (i.e., where deteriorated coating had been sanded to quality foam), the new coating effectively bridged over the transition from foam to old coating. After 5 years of weathering, some cracking of the maintenance coating was evident. This minor cracking was more prevalent on system 3F-1 than on system 3F-2. The third system in this group, system 3F-3, had failed after 5 years of weathering. There were many interface areas of old coating to foam; the maintenance coating was unable to bridge this transition and is cracking around these areas.

System 4F-1 is providing good protection to the PUF after 5 years of exposure. The old weathered coating on this panel had no more than 10% spalled areas, which had been sanded to remove degraded coating and foam. This caused some cracking of the maintenance coating where it had originally bridged these transition areas between sanded foam and old coating. System 4F-2, on the other hand, had more than 40% spalling of the original weathered coating, and about this percentage of the panel had been sanded lightly to good-quality foam. There were relatively few breaks in the maintenance coating where it had been applied over areas of transition from sanded foam to good-quality coating. System 4F-2 was rated very good after 5 years of exposure.

A comparison of the adhesive characteristics of systems 3F and 4F (Table 5) does not show a clear-cut advantage for either using or not using a primer. The reason for this is believed to be the variability of the substrate that was maintained. In some cases, the primer was applied to the sanded foam, while in other cases it was applied to weathered coating (i.e., variable test results may be caused by the primer being applied over different substrates). It is emphasized that there was no loss of adhesion of new coating to old weathered coating with any of the systems mentioned above. The new coating was well bonded to the old coating in every case.

Systems 5F-1 through 8F-1 required complete removal of old deteriorated coating and foam using the disk sanders. As mentioned above, the residual urethane elastomeric coatings (systems 5F-1 and 6F-1) are very tough and abrasion resistant, and their removal with a disk sander is not only time consuming but also tends to gum up the disk sanders, requiring frequent changing of the disk. The weathered butyl-hypalon systems (systems 7F-1 and 8F-1) were not quite as difficult to remove because they have less abrasion resistance than the urethane elastomers. Use of the heavy-duty foam scarfer may produce better results in such situations.

Systems 5F-1 and 6F-1 both performed in an excellent manner, providing complete protection to the sanded foam substrate for up to 5 years (see Table 4). The catalyzed urethane elastomer bonded very well to the sanded foam surface except for a few blisters between the sanded foam surface and the new coating. Use of the primer in system 6F-1 appeared to have minimized the blistering, which is probably caused by isolated larger cell structure at the sanded foam surface. The urethane primer provided a definite improvement in adhesion of the coating to the sanded foam surface, which may be increasing with continued exposure (see Table 5). Application of a coating to a sanded or scarfed foam surface, whether primed or not, is generally not recommended. However, these results suggest that such a procedure would be acceptable in small, isolated areas. When small areas are sanded to provide a smoother surface, the sanded areas should be primed, and at least one additional base coat beyond that specified for the total roof should be applied in the sanded/primed area.

Systems 7F-1 and 8F-1 have also performed in an excellent manner for the 5 years of exposure. These two systems, sanded foam surface that was refoamed and the new foam coated, were similar except for the primer applied to the sanded foam of system 8F-1. Because of the new foam catalyzed urethane coating system, these two systems would be expected to perform well. They were included to determine if priming of the sanded foam surface is advantageous prior to refoaming. Data in Table 6 for these two systems show that the adhesive character of the new foam to old foam is enhanced by use of the primer.

Phase 2

The objective of this phase of the work was to obtain quantitative data relative to the effectiveness of two levels of brooming and sanding, as well as to determine whether or not it is advantageous to prime prior to coating or foaming over old weathered coatings or over sanded foam surfaces (see Table 3).

Two levels of brooming were investigated. The first, systems 9F-1 and 9F-2 and 10F-1 and 10F-2, utilized a rattan push broom, which did a very effective job at cleaning dirt, chalk, loose coating, and deteriorated foam from the panels. The second treatment, designated as brushing, was utilized on the remainder of the weathered TT-P-95 panels, including panels 11F-1 and 11F-2 through 14F-1 and 14F-2. It was found that brushing was not nearly as effective for removing products of PUF roofing system deterioration as the rattan push broom.

The weathered uncoated foam panels were very easily and efficiently cleaned of degraded foam using the disk sander (systems 15F-1 and 15F-2 through 18F-1 and 18F-2). Figures 11a through 11d show the sanded, primed, and coated panel of system 16F-2. Figure 12 shows system 16F-1 after 4 years of exposure. This system is performing well at this time.

The second panel of each series (i.e., 9F-2, 10F-2, etc.) was returned to NCEL on a periodic basis, a small section cut off for adhesion testing, the exposed surfaces coated, and the panel returned to the test rack. The series has been exposed for a period of about 4 years. The coating on those systems whose surfaces were prepared for recoating by brooming or brushing (i.e., systems 9F-1 to 12F-2) showed a very slight tendency to crack where the new coating bridged over cracks in the original coating or over small spots where the original coating had flaked from the foam. However, this was not serious, and all of the systems in this series were providing excellent protection to the coated foam substrate. One factor observed was that when an elastomeric coating is applied over a sanded foam surface, the coating is more easily compressed into the foam than when the coating is applied over a foam surface with a skin (i.e., the skin tends to make the foam surface more rigid). Thus, a coating applied over a sanded foam surface may be more easily damaged. It is for this reason that sanding of the foam followed by an extra heavy coating should be used only in small, isolated areas.

The effect of using a butyl primer on the adhesion of new coating to a weathered coating surface or to a sanded foam surface is given in Table 5. The data show lower adhesive values for the primed surfaces than for the unprimed surfaces, which is a reverse of that found when using the urethane primer in Phase 1. While the differences between the adhesive values for primed and unprimed surfaces were substantial after 1 year of exposure, these appear to be reduced with additional exposure. This suggests that the problem may involve solvents of the butyl primer and solvent retention during the initial exposure period. The retained solvent may tend to migrate out of the system with additional time of exposure, thereby narrowing the difference in the adhesive value between primed and unprimed surfaces.

Application of the butyl primer over a brushed, weathered coating and over a sanded foam surface prior to refoaming increased the adhesive characteristics of the new foam to those surfaces (Table 6). The reason for this is not clear since, as noted above (Table 5), the butyl primer did not enhance the adhesive character of the acrylic elastomer coating to the different surfaces. However, because of the lower incidence of blistering when a coating is applied over a sanded foam surface, the better adhesive character of new foam to old when using the butyl primer, and the overall enhanced adhesion characteristics with the urethane primer, use of a primer appears desirable.

Phase 3

The 108 PUF roofing systems on the family housing units at NAS Lemoore, Calif., that were refurbished in the fall of 1977 have been in place for almost 6 years. About two-thirds of these roofs are performing well and currently require little or no maintenance. Four to six of the units have had moderate to extensive maintenance conducted recently (i.e., blistered or delaminated foam, or foam that was wet or a poor quality, was removed and the areas were refoamed and coated). The remaining one-third of the 108 units have isolated examples of blistering, foam delamination, cracking of the coating, or spongy foam (off-ratio foam). These areas should receive proper and prompt maintenance as soon as possible to prevent accelerated deterioration and failure of the affected roofs. Maintenance procedures should include (1) cutting out and removing any blistered, delaminated, poor-quality or wet foam; (2) beveling the edges of cut-out areas; (3) allowing the area to dry if wet; and (4) refoaming and coating new foam. Cracked or flaked coating areas should be sealed with an appropriate caulking material. If the existing coating is severely aged, these units should be recoated.

The actual reason for the problems in the PUF roofs showing early deterioration has not been determined. However, it is believed to be caused by the attempt to save as much of the original PUF roof as possible. The original PUF had been applied over lightweight concrete, which was used to provide slope over a flat BUR. Blistering or delamination of the foam can be attributed to several factors: (1) moisture in the original foam or in the lightweight concrete, (2) original foam too thin after sanding, (3) poor bond between the original foam and the lightweight concrete, or (4) questionable integrity of the lightweight concrete. In all probability, the principal problem lies with number (3) or (4). If the original foam is not well bonded to the lightweight concrete or if the lightweight concrete does not have good integrity, stresses that develop in the new foam as it ages could cause the foam to disbond from the substrate, causing blistering or delamination problems.

The results to date on this refurbishing suggest that this is a very satisfactory maintenance procedure. However, the problems that have been observed indicate the requirement for a very rigorous inspection of the original foam roofs once they have been scarfed or sanded to be assured that the existing foam is dry and well bonded to a sound, dry substrate. It would probably be prudent in such a case to have moisture surveys of the roofs to establish that they are in fact dry. Considering the good performance of the majority of these roofs, the alternative and considerable additional expense of a complete tear-off of the original foam, the lightweight concrete fill, and the BUR membrane, the procedure used is considered a very viable alternative.

Phase 4

This phase of the investigation deals with maintenance of small areas of a PUF roof rather than the total roofing system. It is firmly believed that this small maintenance activity should be carried out in conjunction with annual inspections. During such inspections, very small defects can be corrected with caulking material carried by the inspector. During the annual inspections at the NRC Clifton test site (Ref 6), it was a relatively simple matter to remove degraded coating/ foam areas from small spots on the roof and repair them on the spot with either silicone or acrylic caulking material. Such a procedure often prevents small problems from becoming large roof defects.

If a defect 1 ft^2 or larger is found during the annual inspection or noted at other times, it then becomes necessary to use the maintenance procedures for small areas. As described in the EXPERIMENTAL INVESTIGATIONS section, single- and two-component "canned" foams and precut foam insulation boardstock were investigated.

The single-component "Handi-Foam" did not perform in an acceptable manner. Although this froth foam filled the voids relatively well, the cell structure of the foam was very irregular, resulting in extremely poor physical characteristics and causing the applied coating to spall within 1 year. The poor-quality patches and foam required removal and replacement the following year. NCEL experience with Polycel 1 has been more favorable in that it provides a better quality foam material with a more uniform cell structure. It must be emphasized that the single-component materials require a curing time of about 24 hours before they can be shaped or coated. Where station forces are performing the maintenance, such a delay may not be a problem.

The two-component canned foams also expanded and filled the voids well but, like the single-component foams, produced a very rough surface that had to be shaped. This froth foam will not only cure within 1 to 2 hours, but it also provides a better quality foam with better cell structure than that obtained with the single-package materials. Because of the short curing time, the two-component foams can be shaped with a disc sander within 2 hours after application. As an alternative to sanding, a relatively flat surface can be obtained by placing a piece of plywood wrapped in polyethylene over the foamed patch as it is applied. A weight can be placed on top of the plywood to hold it in place, and the foam then rises against and conforms to the flat surface of the weighted plywood. After the proper curing time (i.e., 24 hours for single-component foam or about 2 hours for two-component foam), the plywood can be removed and the foam patch coated with the proper coating or caulking material.

If the canned foam is not available, PUF or styrofoam boardstock insulation appears to be an acceptable alternative. This is adhered to the roof deck with caulking material, shaped (if required), and then waterproofed or protected from the environment with either a suitable coating or caulking material. This procedure has worked relatively well for over 2 years in tests conducted at NCEL.

Of the three methods mentioned, NCEL believes that the two-component canned foams provide a better patch than either the single-component canned foam or the foam boardstock. Among other factors, the two-component canned foams provide a monolithic roofing system consisting of essentially the same foam material as the original roof, although these foams are generally of slightly lower density (i.e., less than 2 lb/ft^3). The single-component foams are somewhat different chemically, and the boardstock introduces a cold joint around the perimeter of the patch.

Shaping of the foam does give a sanded or cut foam surface without the normal foam skin. As noted earlier, a sanded foam surface is normally not recommended except for small, isolated areas, since the coating over a sanded surface is more easily damaged than a coating over a skinned surface. It was observed in tests at NRC Clifton that when only two coats of silicone coating were applied over the shaped surfaces, the coating would start to deteriorate in a couple of years, while the caulking material, which is similar but thicker, has held up very well for up to 5 years. When coating is used over a sanded foam surface, it should be applied in multiple coats to provide a minimum dry film thickness of 35 to 40 mils. The coating would have to be applied over at least a 2-day period, which could cause logistic problems. As a result, NCEL favors the use of caulking materials for the patching operation, which permits protecting the foam in one operation.

New, small, foam spray machines are currently available for small foam roof repairs. These machines, which have small canisters of the two foam components on the unit and require only a 110-volt power source and low-pressure, low-volume compressed air (1 cfm), provide the best maintenance procedure because the two-component foam used is the same quality as in the original roof. Where a base has a number of foam roofs, such as on family housing, the procurement and use of this type of equipment could be most beneficial and cost effective. The Model FF-111 Little Big Shot™, available from Gusmer Corp., is one type of foam spray machine.

<u>Phase 5</u>

Results of the research to determine the adhesion of new silicone coatings over weathered silicone coatings are presented in Table 7. The single-component silicones were applied over weathered silicones that had received one of four different surface treatments: (1) broomed, (2) washed with water, (3) washed with moderate pressure water blasting (i.e., 100+ psi), and (4) washed with detergent. A study of the adhesion data in Table 7 suggests that brooming would normally be an adequate surface preparation, although there is not much difference in the adhesive values between the coatings applied over the four different surface treatments. However, in certain heavy industrial atmospheres, oily substances may be deposited on the roof, and washing with detergent may be required to properly prepare the surface. There appears to be a trend in which the adhesive values increase in each of the four cases. The adhesive values, in fact, show a tendency to increase to the values determined previously for the adhesion of this silicone coating to foam (i.e., 9 to 10 kg/cm^2 (Ref 7)). In this latter case, failure of the system always occurred cohesively in the foam. In the current study

(Table 7), failure was normally an adhesive failure between the new and old coating. This is not serious because the adhesion of the new to old coating appears to increase with time. While there have been some problems in the past with the adhesion of the single-component, moisture-cured silicone to foam, a new base coat of this material has recently been introduced that has incorporated an adhesion promoter. The new base coat is expected to enhance the adhesive character of this system and is being investigated.

FINDINGS AND CONCLUSIONS

1. A PUF roofing system can be easily maintained using methods and materials described in this report.

2. A strong inspection and maintenance program can extend the time for recoating as much as an additional 5 years.

3. When removing small areas of poor-quality, wet, or degraded foam, the areas should be refoamed with conventional foaming equipment. If this equipment is not available, repairs can be made using two-component canned foam or foam boardstock. Any voids between new and old foam should be caulked and the new foam surface protected with appropriate caulking material or 35 to 40 mils of elastomeric coating.

4. If spalling of weathered elastomeric coating is distributed uniformly over the roof and is less than 10%, the roof can generally be satisfactorily recoated. In such cases, a tiecoat of primer recommended by the coating manufacturer should be applied before recoating. While use of the primer may or may not enhance the adhesion of the new coating to the weathered coating, depending on the primer employed, it does appear to improve the overall performance of the coating.

5. New sprayed PUF applied over an existing primer-coated foam system has performed very well in these studies. While such a procedure is not applicable in all cases, it can be used. Each application should be considered on a case-by-case basis.

RECOMMENDATIONS

1. A strong annual inspection and maintenance program should be instituted to prolong the life expectancy of foam roofs and extend the time between recoating cycles.

2. The preliminary procedures specified in this report should be tested in full-scale field trials to determine their effectiveness.

3. Coating a sanded foam surface is generally not recommended. However, coating small, isolated areas (approximately 5 to 10 ft^2 appears to present no problem as long as the area is not a high traffic area and the coating thickness is at least 35 to 40 mils.

4. When refoaming over an existing coated foam roof, the roofing system should be thoroughly inspected for roof defects to ensure that it is dry (by means of a nuclear survey or other specialized inspection technique); any wet or degraded areas should be removed, allowed to dry, and refoamed; and the weathered surfaces should be cleaned and primed prior to refoaming. Additional foam should not be applied over an impermeable coating or over a silicone-coated foam roof.

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Table 1. Deteriorated Polyurethane Foam (PUF) Roofing System Panels Maintained in Phase 1

System Number	Designation and Color	Foam Density (lb/ft^3)	No. of Coats	Dry Film Thickness (mils)	Total (mils)	Months Exposed	Condition of PUF Roofing Systems
3	Catalyzed butyl-hypalon • Butyl base coat, black • Hypalon topcoat, white	2.0	 1 1	 13 5	18	12-47	At CL[a] and PM sites coating systems failed by topcoat peeling from base coat and deterioration of base coat after 12 months. At PH site system failed after 47 months.
10	Aluminum-pigmented catalyzed urethane elastomer • Catalyzed urethane elastomer, aluminum	2.0	1	-	26	36-40	At all three sites coating flowed from high points of foam surface when applied; failed by flaking of coating from high points; most severe at PH and PM.
14	Moisture-cured urethane • Elastomer, gray	2.0	1	-	42	13-18	Coating very irregular in thickness; thinner spots failed, exposing foam to degradation.
14A	Moisture-cured urethane • Elastomer, gray	2.5	2	-	39	23	Coating applied correctly but failed by crazing and flaking, exposing foam to degradation.

[a]Test sites designated as follows: CL = China Lake, PM = Pickel Meadows, PH = Port Hueneme. There was one panel of each of the 4 systems at each of the 3 exposure sites for a total of 12 panels.

Table 2. Description of Maintenance Procedures - Phase 1

System Number	Description of Procedure	Original System Number	Original System Description	Primer	New Foam	New Coating System	Remarks
1F-1	Broom and coat	3-1	2.0-lb/ft^3 foam; butyl-hypalon coating	None	None	Gaco U-66[a]	
1F-2		14-9	2.5-lb/ft^3 foam; moisture-cured urethane	None	None	Gaco U-66	
2F-1	Broom, prime, and coat	14-6	2.5-lb/ft^3 foam; moisture-cured urethane	Plas Chem[b] 9002-1FR urethane	None	Gaco U-66	
3F-1	Broom, sand some portions, and coat	10-1	2.0-lb/ft^3 foam; catalyzed urethane	None	None	Gaco U-66	<10% of panel sanded
3F-2		10-3	2.0-lb/ft^3 foam; catalyzed urethane	None	None	Gaco U-66	<10% of panel sanded
3F-2		14-3	2.0-lb/ft^3 foam; catalyzed urethane	None	None	Gaco U-66	<40% of panel sanded
4F-1	Broom, sand some portions, prime, and coat	10-4	2.0-lb/ft^3 foam; catalyzed urethane	Plas Chem 9002-1FR urethane	None	Gaco U-66	<30% of panel sanded
4F-2		14-8	2.5-lb/ft^3 foam; moisture-cured urethane	Plas Chem 9002-1FR urethane	None	Gaco U-66	<10% of panel sanded
5F-1	Sand entire panel and coat	14-1	2.0-lb/ft^3 foam; moisture-cured urethane	None	None	Gaco U-66	
6F-1	Sand entire panel, prime, and coat	14-4	2.0-lb/ft^3 foam; moisture-cured urethane	Plas Chem 9002-1FR urethane	None	Gaco U-66	
7F-1	Sand entire panel, foam, and coat	3-3	2.0-lb/ft^3 foam; butyl-hypalon coating	None	Witco SS-0125A/ SS-0126B[c] (3.0 lb/ft^3)	Gaco U-66	
8F-1	Sand entire panel, prime, foam, and coat	3-4	2.0-lb/ft^3 foam; butyl-hypalon coating	Plas Chem 9002-1FR urethane	Witco SS-0125A/ SS-0126B (3.0 lb/ft^3)	Gaco U-66	

[a]Gaco U-66 is a catalyzed urethane elastomer system produced by Gaco-Western, Seattle, Wash.

[b]Plas-Chem 9002-1FR is a catalyzed urethane primer produced by Plas-Chem, St. Louis, Mo.

[c]Witco SS-0125A/SS-0126B foam is a product of Witco Chemical, New Castle, Del.

Table 3. Description of Maintenance Procedures - Phase 2[a]

System Number	Description of Procedure	Original System Description	Primer	New Foam
9F-1 and 9F-2	Broom and coat	TT-P-95 coating over Witco SS-0125A/SS-0126B[b] foam (3.0 lb/ft^3)	None	None
10F-1 and 10F-2	Broom, prime, and coat	TT-P-95 coating over Witco SS-0125A/SS-0126B foam (3.0 lb/ft^3)	United[c] 838 butyl	None
11F-1 and 11F-2	Brush and coat	TT-P-95 coating over Witco SS-0125A/SS-0126B foam (3.0 ft/lb^3)	None	None
12F-1 and 12F-2	Brush, prime, and coat	TT-P-95 coating over Witco SS-0125A/SS-0126B foam (3.0 lb/ft^3)	United 838 butyl	None
13F-1 and 13F-2	Brush, foam, and coat	TT-P-95 coating over Witco SS-0125A/SS-0126B foam (3.0 lb/ft^3)	None	Witco SS-0125A/ SS-0126B (3.0 lb/ft^3)
14F-1 and 14F-2	Brush, prime, foam, and coat,	TT-P-95 coating over Witco SS-0125A/SS-0126B foam (3.0 lb/ft^3)	United 838 butyl	Witco SS-0125A/ SS-0126B (3.0 lb/ft^3)
15F-1 and 15F-2	Sand and coat	Weathered, uncoated foam - Witco SS-0125A/SS-0126B (3.0 lb/ft^3)	None	None
16F-1 and 16F-2	Sand, prime, and coat	Weathered, uncoated foam - Witco SS-0125A/SS-0126B (3.0 lb/ft^3)	United 838 butyl	None
17F-1 and 17F-2	Sand, foam, and coat	Weathered, uncoated foam - Witco SS-0125A/SS-0126B (3.0 lb/ft^3)	None	Witco SS-0125A/ SS-0126B (3.0 lb/ft^3)
18F-1 and 18F-2	Sand, prime, foam, and coat	Weathered, uncoated foam - Witco SS-0125A/SS-0126B (3.0 lb/ft^3)	United 838 butyl	Witco SS-0125A/ SS-0126B (3.0 lb/ft^3)

[a]The new coating system for this phase consisted of two coats of Diathon at 1-1/2 gal/sq/coat. Diathon is a product of United Coatings, Spokane, Wash.

[b]Witco foam is a product of Witco Chemical, New Castle, Del.

[c]United 838 butyl primer is a product of United Coatings, Spokane, Wash.

Table 4. Performance Ratings for Polyurethane Foam (PUF) Maintenance Systems

System Number	Description of Maintenance Procedure	Primer	New Foam Density (lb/ft^3)	Performance Ratings on Weathering[a] 4 Mo	1 Yr	2 Yr	3 Yr	4 Yr	5 Yr
			Phase I						
1F-1	Broom panel and coat	none	none	VG-G	VG-G	VG-G	VG-G	G	G
1F-2		none	none	G	P-F	F	F	F	F
2F-1	Broom panel, prime, and coat	none	none	E	VG	G	G	G	P
3F-1	Broom panel, sand some portions, and coat	none	none	E-VG	VG	VG-G	VG-G	VG-G	VG-G
3F-2		none	none	VG	VG	VG	VG	VG	VG
3F-3		none	none	VG	VG-G	G	G	P	F
4F-1	Broom panel, sand some portions, prime, and coat	urethane	none	VG	VG	VG	VG	VG-G	G
4F-2		urethane	none	VG	VG	VG	VG	VG	VG
5F-1	Broom, sand entire panel, and coat	none	none	E	E	E	E	E	E
6F-1	Broom, sand entire panel, prime, and coat	urethane	none	E	E	E	E	E	E
7F-1	Broom, sand entire panel, foam, and coat	none	3	E	E	E	E	E	E
8F-1	Broom, sand entire panel, prime, foam, and coat	urethane	3	E	E	E	E	E	E
			Phase II						
9F-1	Broom panel and coat	none	none	E	E	E	E	E	-
10F-1	Broom panel, prime, and coat	butyl	none	E	E	E	E	E	-
11F-1	Brush panel and coat	none	none	E	E	E	E	E	-
12F-1	Brush panel, prime, and coat	butyl	none	E	E	E	E	E	-
13F-1	Brush panel, foam, and coat	none	3	E	E	E	E	E	-
14F-1	Brush panel, prime, foam, and coat	butyl	3	E	E	E	E	E	-
15F-1	Sand entire panel and coat	none	none	E	E	E	E	E	-
16F-1	Sand entire panel, prime, and coat	butyl	none	E	E	E	E	E	-
17F-1	Sand entire panel, foam, and coat	none	3	E	E	E	E	E	-
19F-1	Sand entire panel, prime, foam, and coat	butyl	3	E	E	E	E	E	-

[a]Performance ratings were assigned as follows:

E = Excellent. The system is performing without any noticeable deterioration.
VG = Very Good. Only very minor deterioration of the system.
G = Good. Although the maintained PUF systems show deterioration, it is not serious.
P = Poor. System deterioration is serious. Remedial action will be required in the near future.
F = Failed. Deterioration of the system has advanced to the point of requiring immediate maintenance.

Table 5. Adhesive Properties of Coatings on Polyurethane Foam (PUF) Maintenance Panels

System Number	Primer	Adhesive Properties for Approximate Exposure Times of--							
		1 Year		2 Years		3 Years		4 Years	
		Stress (kg/cm^3)	Failure Mode[a]	Stress (kg/cm^3)	Failure Mode[a]	Stress (kg/cm^3)	Failure Mode[a]	Stress (kg/cm^3)	Failure Mode[a]
Phase I									
1F-1	no	-	-	24.0	4	9.6	7	10.9	7
1F-2	no	-	-	12.3	6	11.1	4	11.1	5/7
2F-1	urethane	-	-	18.9	5/8	17.5	2	15.6	2/8
3F-1	no	-	-	28.3	8	17.5	7/4	15.7	4/8
3F-2	no	-	-	14.6	8	13.4	8/7	15.4	8
3F-3	no	-	-	18.7	8/5	8.6	7/4	7.1	7
4F-1	urethane	-	-	19.0	8	17.2	7/8	13.1	7/8
4F-2	urethane	-	-	21.7	3	13.7	7/8	14.0	7
5F-1	no	-	-	17.7	8	13.3	7/8	11.0	7/8
6F-1	urethane	-	-	18.2	8	17.4	8	15.9	4/8
Phase II									
9F-2	no	26.0	8	42.8	8	15.6	8	11.5	8
10F-2	butyl	20.0	8/3	36.3	8/9	12.0	8/2	9.3	8
11F-2	no	25.4	8	30.2	8	20.6	8	11.5	8
12F-2	butyl	13.8	3	18.1	3	11.6	6/8	7.0	8/7
15F-2	no	14.2	8	30.2	8	15.1	8/6	13.1	8
16F-2	butyl	13.2	8/6	15.0	8/6	14.0	8/6	11.7	8/6

[a] Failure modes were:

1. Adhesive failure of probe to new coating.
2. Adhesive failure of new coating to primer.
3. Adhesive failure of primer to old coating.
4. Adhesive failure of new coating to old coating.
5. Adhesive failure of old coating to foam.
6. Cohesive failure of old coating.
7. Cohesive failure of new coating.
8. Cohesive failure in foam.
9. Adhesive failure of primer to old foam (in areas where old coating spalled from foam).

Table 6. Adhesion of New Foam to Old Foam - With and Without Primer

System Number	Weathered Foam Treatment	Primer Type	Adhesive Properties for Exposure Times of--			
			2.5 Years		4 Years	
			Stress (psi)	Mode[a]	Stress (psi)	Mode[a]
Phase I						
7F-1	Broomed, sanded, and foamed	none	-	-	22	1
8F-1	Broomed, sanded, primed, and foamed	urethane	-	-	26	1
Phase II						
13F-2	Brushed and foamed	none	22.6	1	36	1
14F-2	Brushed, primed, and foamed	butyl	26.7	2/3/4/5	44	2/4
17F-2	Sanded and foamed	none	18.3	1	38	2/1
18F-2	Sanded, primed, and foamed	butyl	34.2	5	42	4/2

[a]Principal mode of failure.

1. Adhesive failure of new foam to old foam.
2. Adhesive/cohesive failure with old foam.
3. Adhesive failure of primer to old foam.
4. Adhesive failure of new foam to primer.
5. Adhesive/cohesive failure within new foam.
6. Bond of old foam to primed plywood.

Table 7. Adhesion of New Silicone Coating to Weathered Silicone (Phase 5)[a]

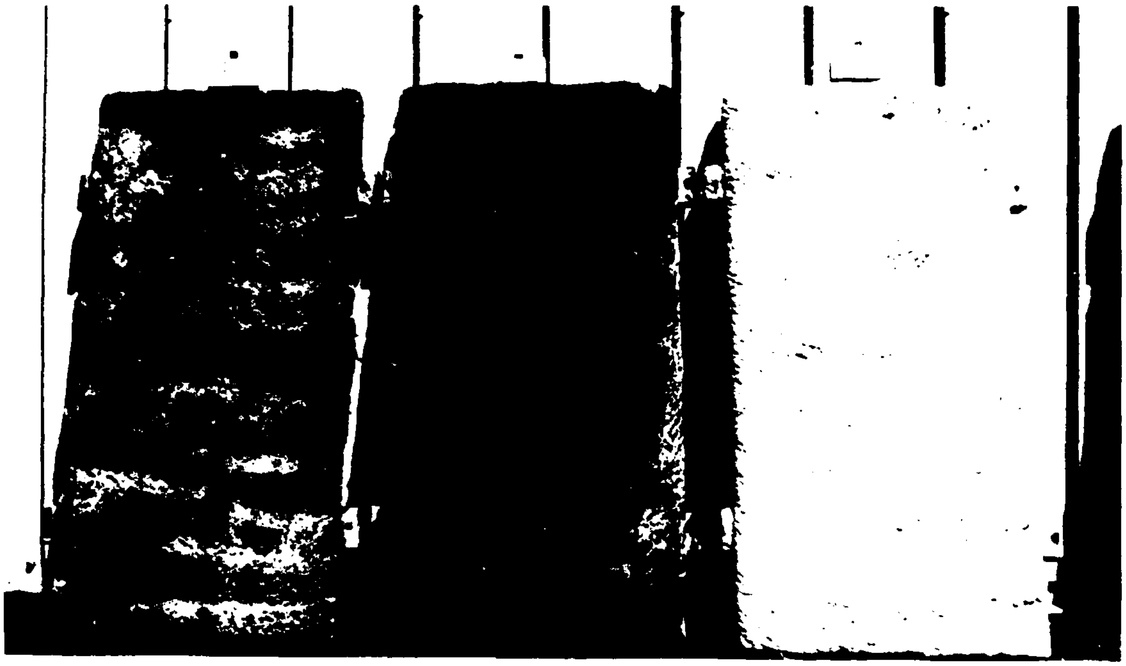
System Number[b]	Surface Treatment	Adhesive Properties for Exposure Times of--				Original Coating System
		Initially		6 Months		
		Stress (kg/cm^2)	Mode[c]	Stress (kg/cm^2)	Mode[c]	
19F-1	Thoroughly broomed to remove adhered dirt	5.5	2	8.9	2/1	Dow Corning 3-5000 exposed at China Lake, Calif., for 8 years. System in excellent condition.
19F-2	Thoroughly broomed, washed with water, and dried completely	6.2	1/2	7.4	2/1	Dow Corning 3-5000 exposed at China Lake, Calif., for 8 years. System in excellent condition.
20F-1	Washed with a pressurized water (~ 100 psi) spray and dried completely	7	2/1	8.6	2	Dow Corning 3-5000 exposed at Pickel Meadows, Calif., for 8 years. System in excellent condition.
20F-2	Washed and scrubbed with trisodium phosphate detergent, rinsed with clean water, and dried completely	6	2/1	7	2/1	Dow Corning 3-5000 exposed at Pickel Meadows, Calif., for 8 years. System in excellent condition.

[a]The recoat system consists of two coats of Dow Corning 3-5000 applied at 1 gal/100 ft^2/coat.

[b]Systems 19F-1 and 19F-2 and 20F-1 and 20F-2, respectively, were each applied to one-half of the panel.

[c]Predominant modes of failure in tension were:

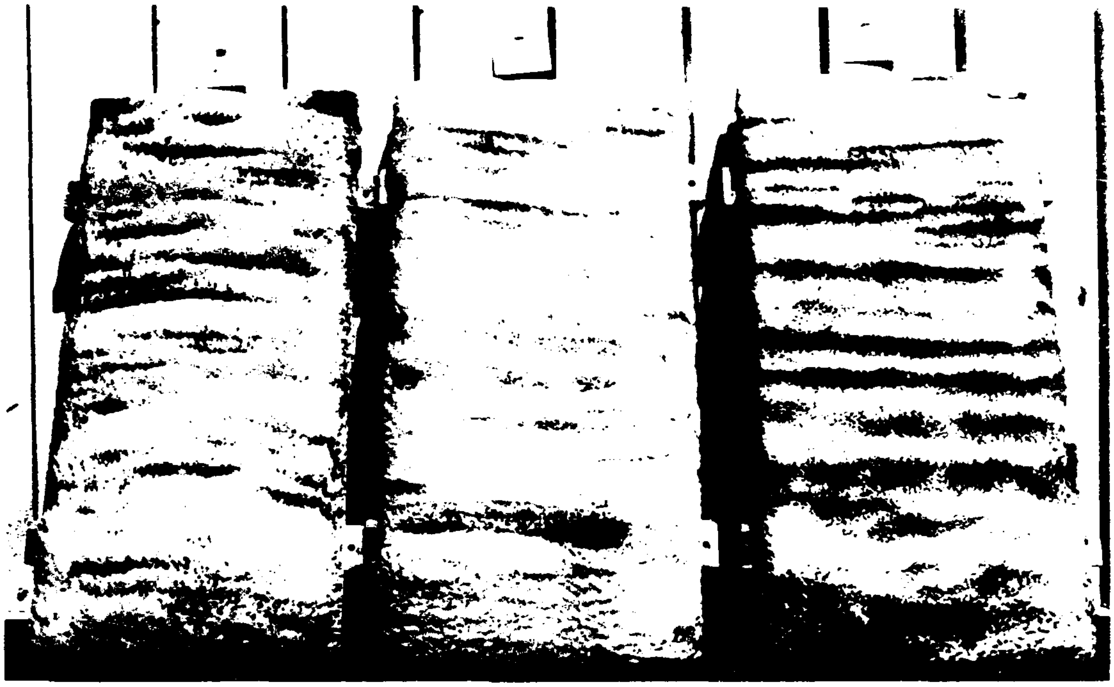
1. Adhesive failure of probe to new coating.
2. Adhesive failure of new coating to old coating.



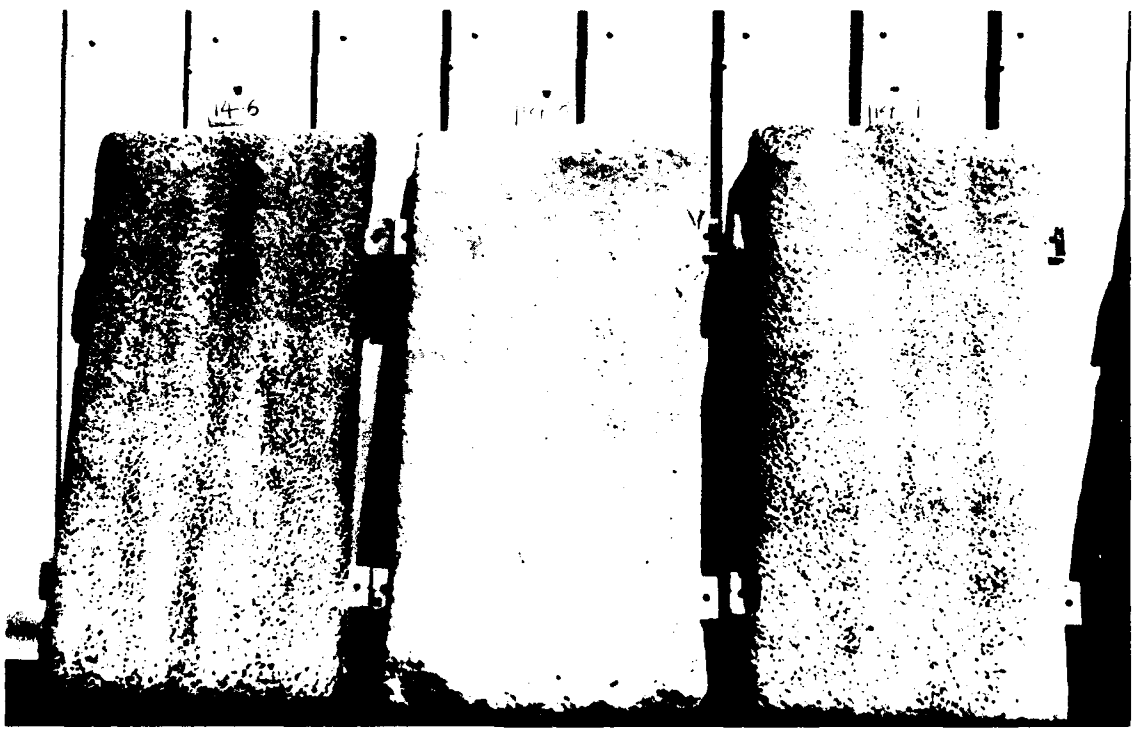
(a) Butyl-hypalon coating (systems 3-4, 3-3, and 3-2).

(b) Aluminum-filled, hydrocarbon-modified, catalyzed urethane coating (systems 10-1, 10-3, and 10-4).

Figure 1. Condition of weathered panels included in Phase 1.



(c) Moisture-cured urethane coating (systems 14-1, 14-3, and 14-4).



(d) Moisture-cured urethane coating (systems 14-6, 14-8, and 14-9).

Figure 1. Continued

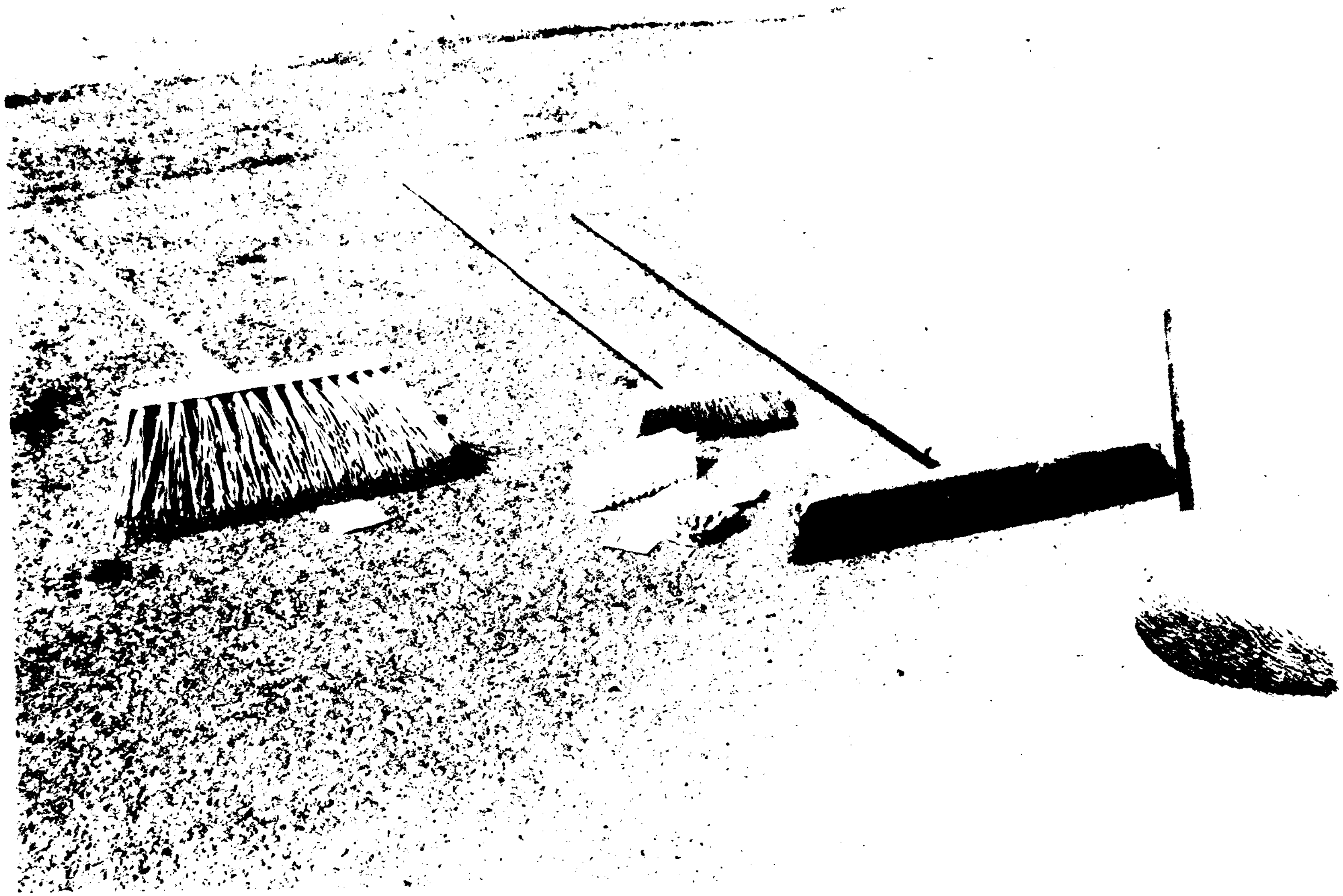
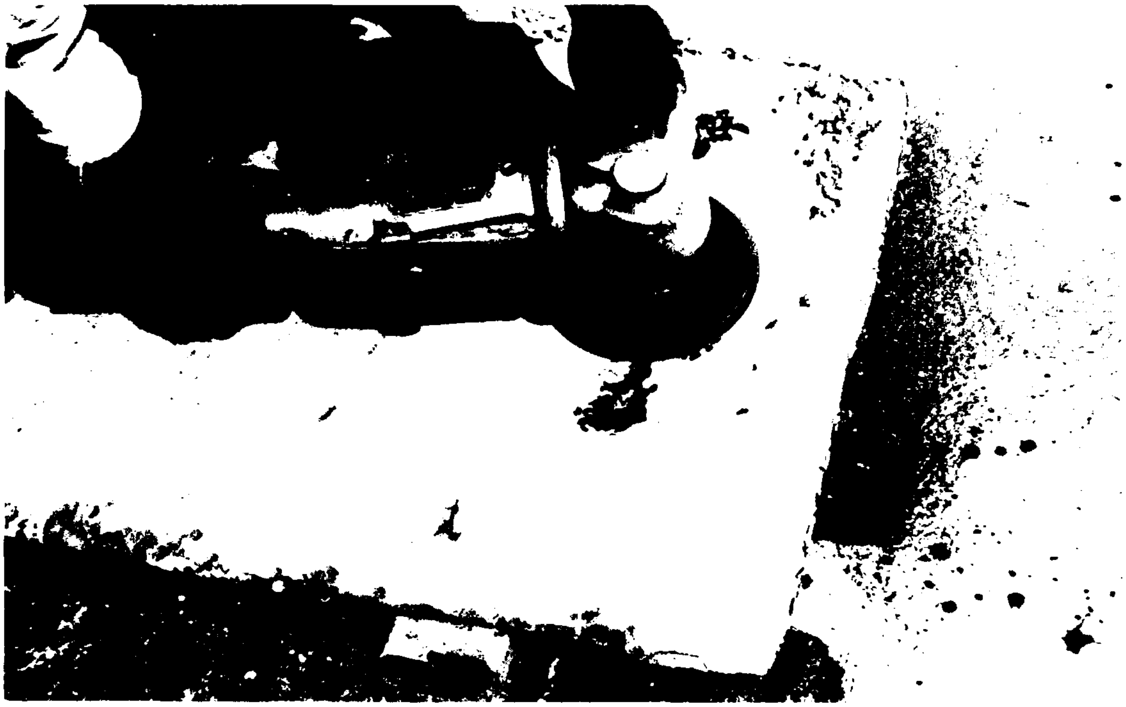


Figure 2. Brooms/brushes used in roof maintenance investigations.



(a) Removal of deteriorated foam/coating with a disk sander.

(b) Removal of deteriorated foam with a Gusmer Foam Plane.

Figure 3. Mechanical removal of deteriorated coating/foam.

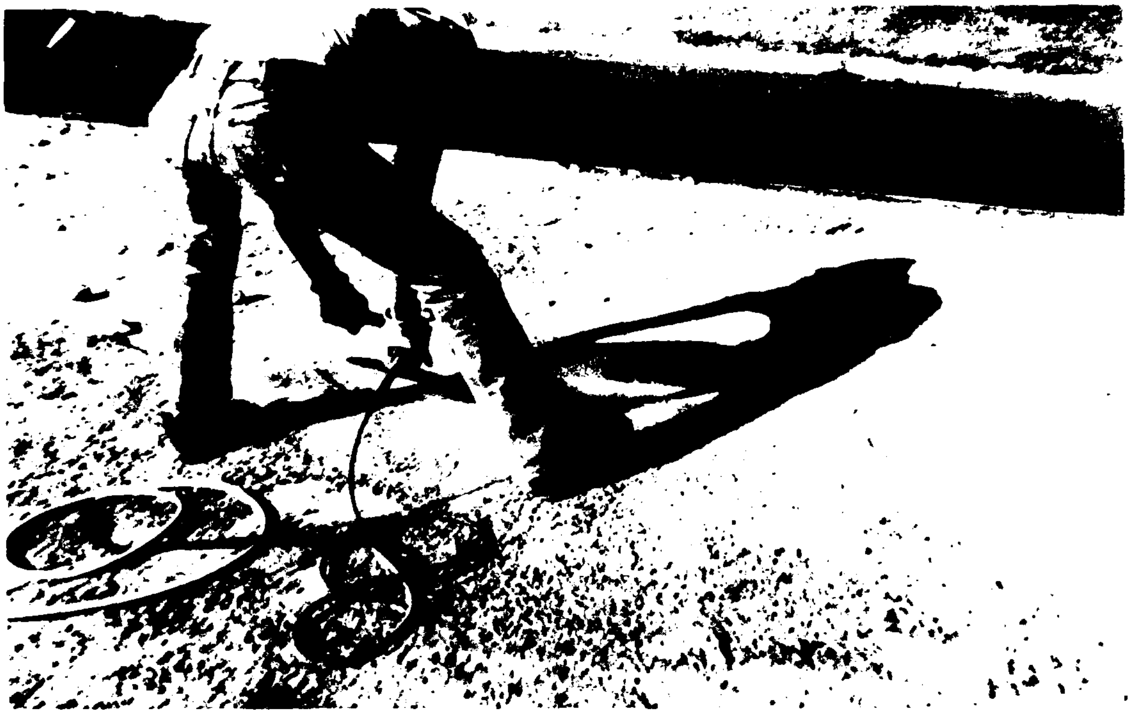


Figure 4. Removal of degraded foam/coating with a heavy-duty disk sander (NAS Lemoore).

Figure 5. Applying an additional 1-1/2 inches of sprayed foam to sanded and primed foam surface.

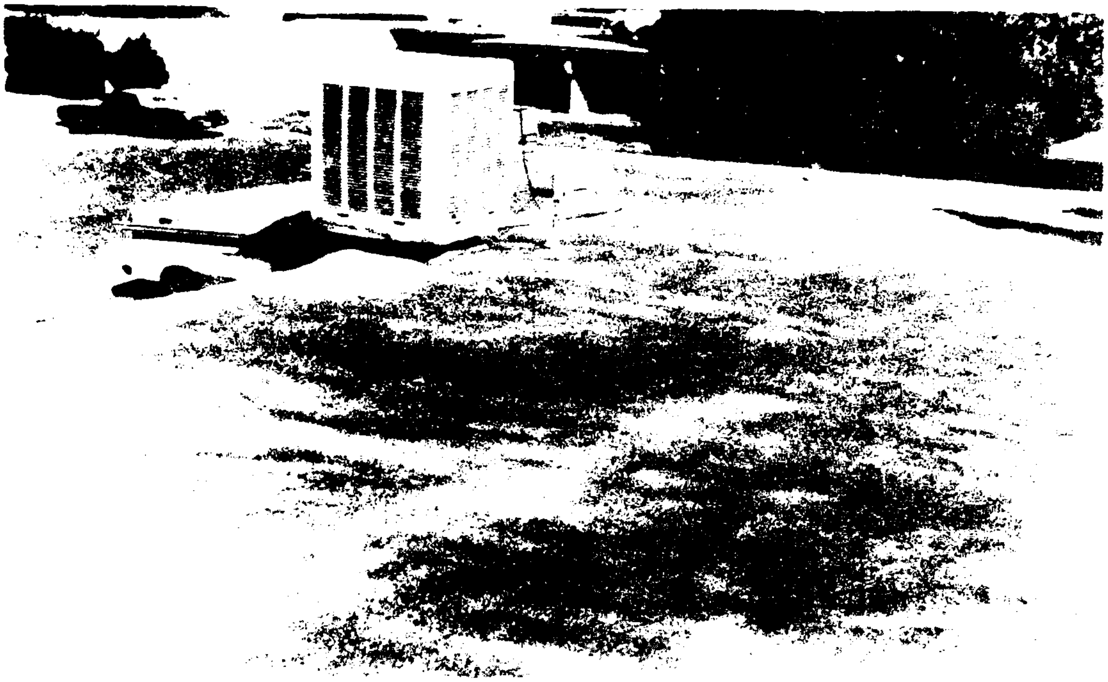


Figure 6. Overview of refurbished polyurethane foam roof with urethane coating and mineral roofing granules (NAS Lemoore).

(a) Old foam is cut out.

Figure 7. Patching polyurethane foam (PUF) roofs with canned foam or boardstock.

(b) Edge of cut is beveled and all debris is removed.

(c) PUF roof is patched with canned foam.

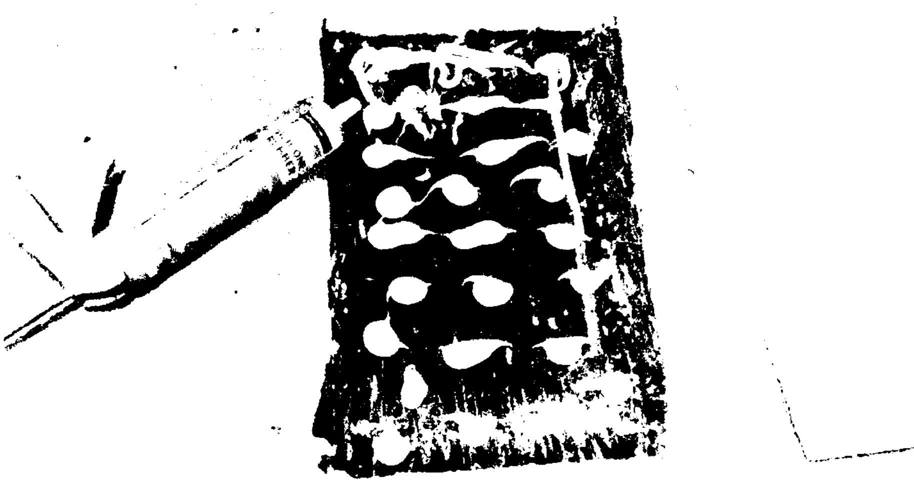
Figure 7. Continued

(d) New foam patch is shaped with a knife.

(e) Cut foam is smoothed with a disk sander.

Figure 7. Continued

(f) Sanded foam is protected with coating or caulking and, where required, roofing granules.



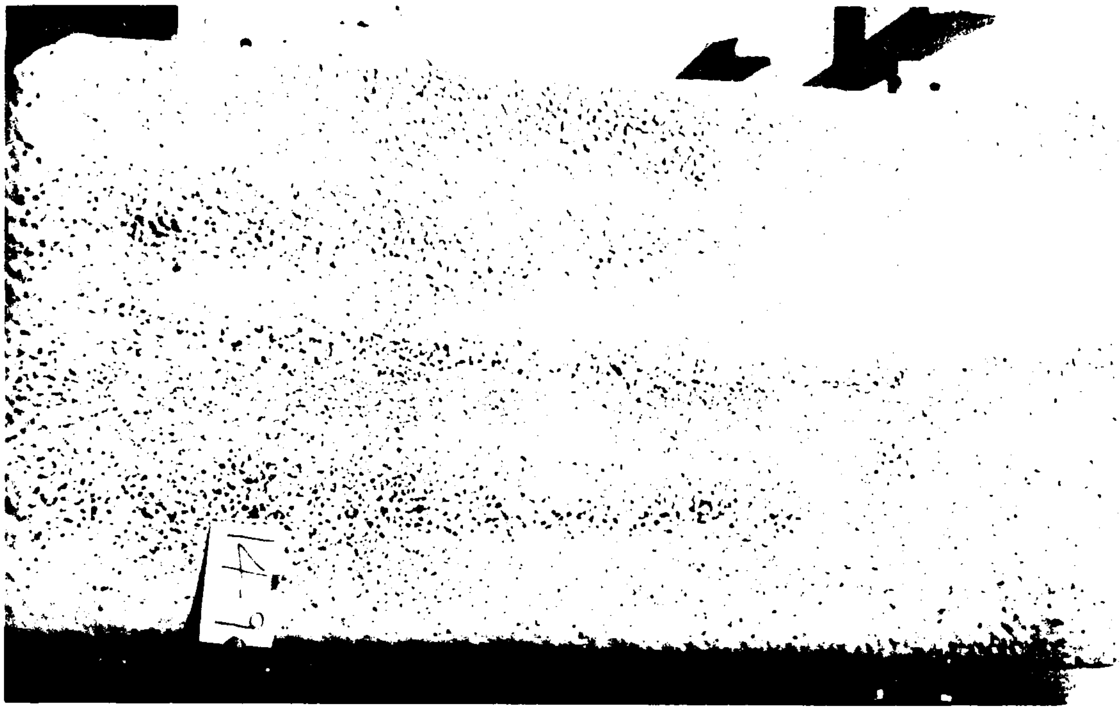
(g) Patch using boardstock is adhered to roof deck with caulking material.

Figure 7. Continued

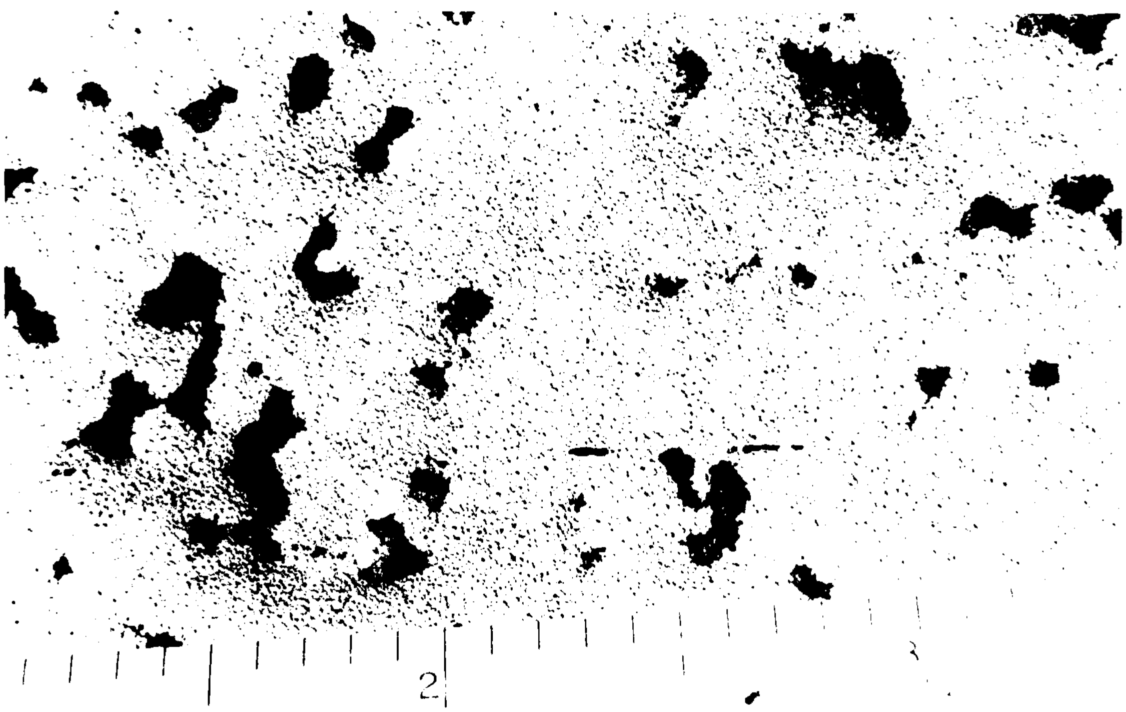
(h) Perimeter of patch is caulked.

(i) Foam patch is protected with caulking material.

Figure 7. Continued

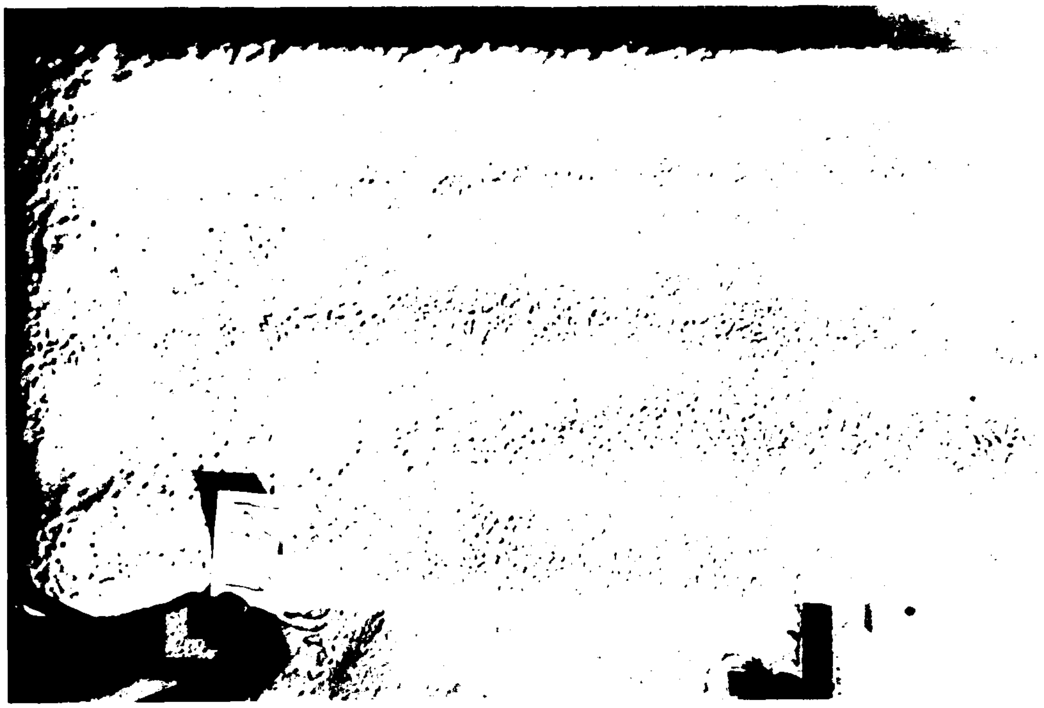


(a) Full panel view.

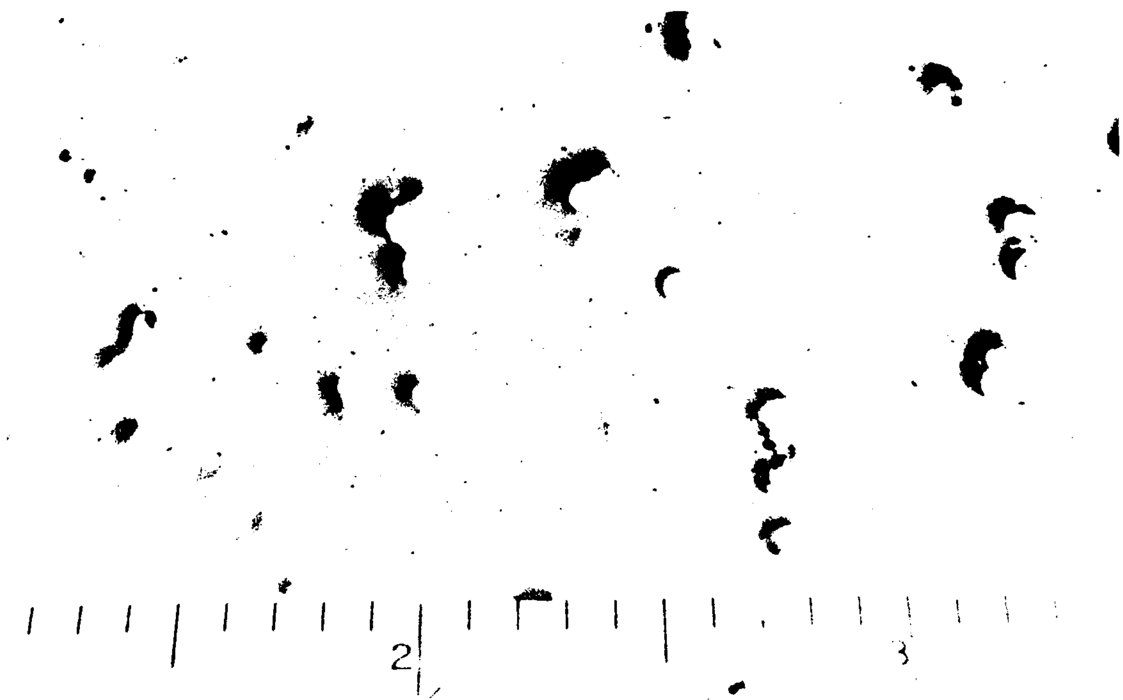


(b) Photomacrograph (~4 in.^{2}).

Figure 8. Weathered moisture-cured urethane-coated foam panel after brooming (system 1F-2).



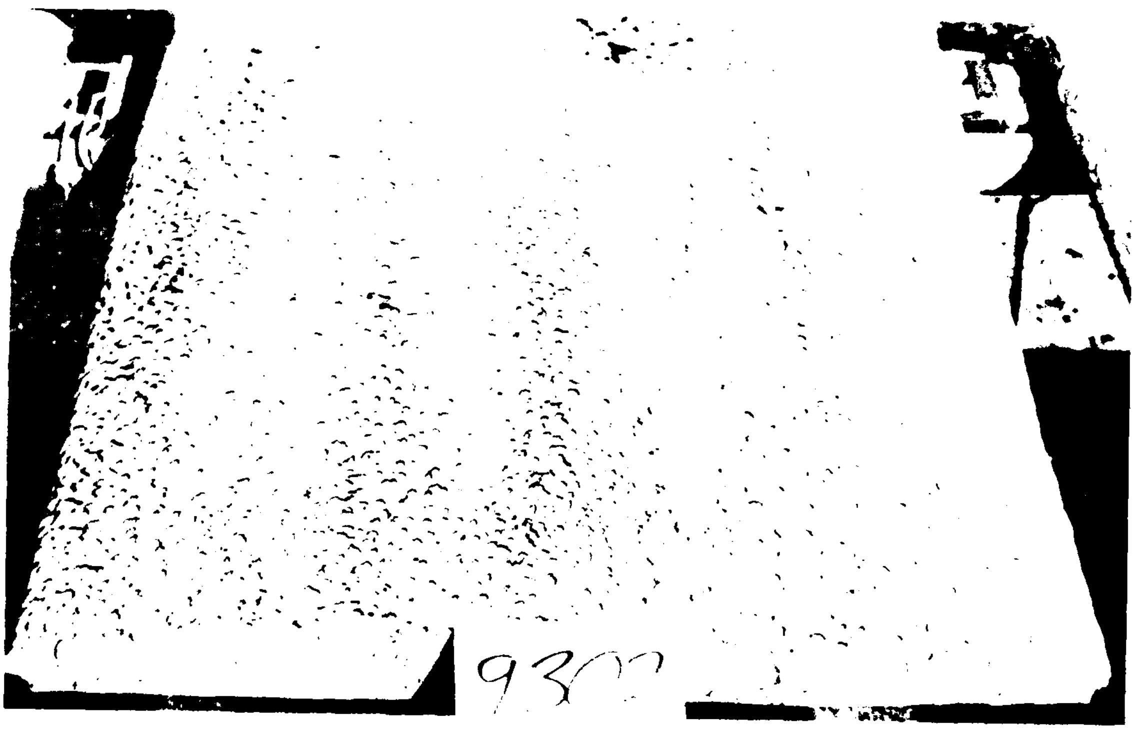
(a) Full panel view.



(b) Photomacrograph (~4 in.^{2})

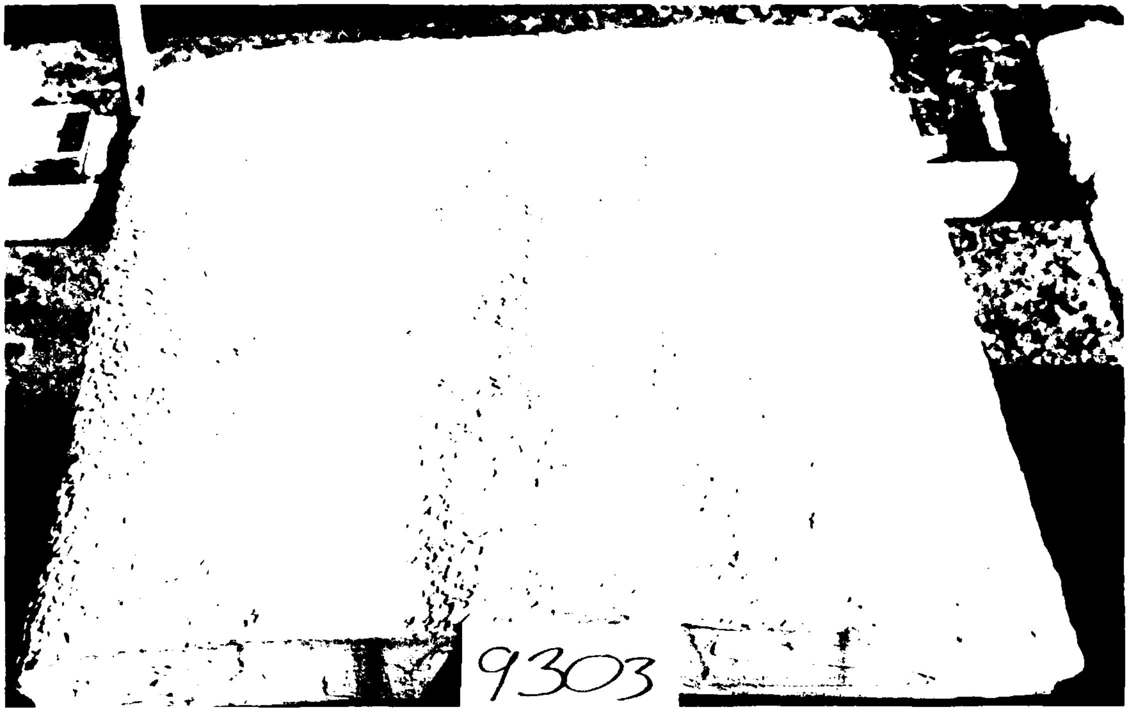
Figure 9. Panel IF-2 after maintaining with a catalyzed urethane coating.

(a) System 1F-2 after weathering for 1 year. Note water and spongy foam when pressed.



(b) System 1F-2 overview after weathering for 5 years. System had failed.

Figure 10. Comparison of systems 1F-2 and 2F-1.



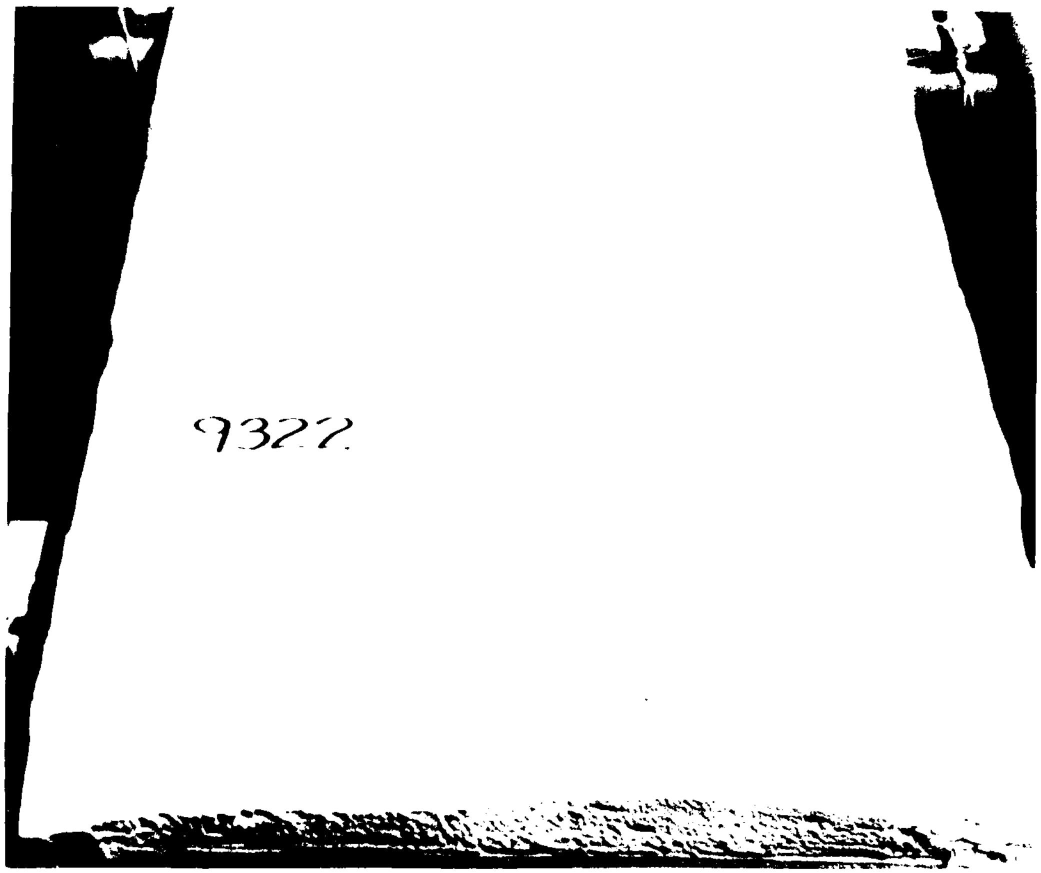
(c) System 2F-1 overview. This system with primer is performing better than system 1F-2 without primer.

Figure 10. Continued

(a) Full panel after sanding.

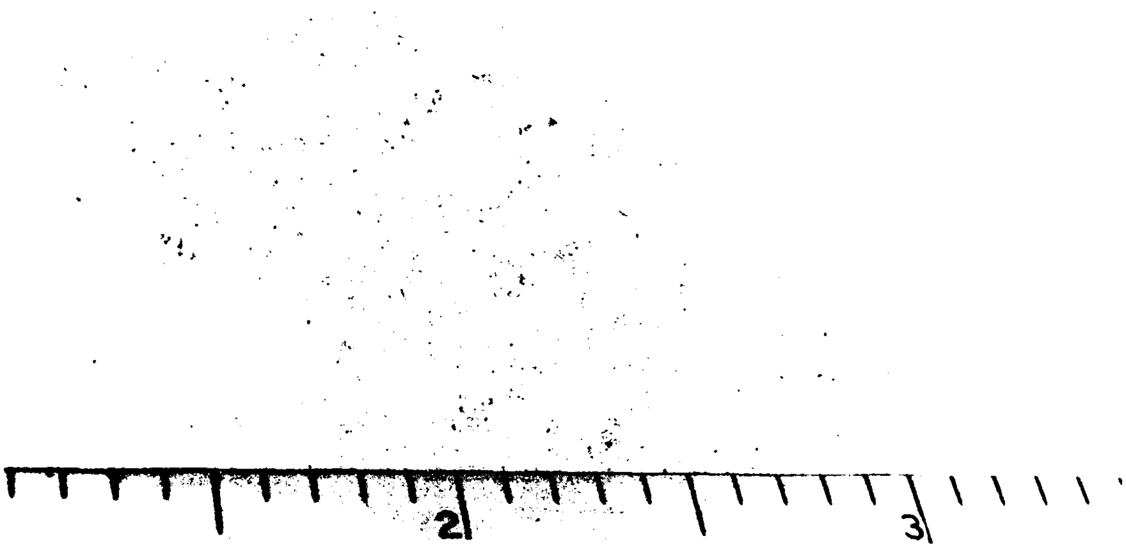
Figure 11. Weathered uncoated control maintained by sanding, priming, and coating with Diathon (system 16F-2).

(b) Full panel after priming.



(c) Full panel after coating with Diathon.

Figure 11. Continued



(d) Photomacrograph of coated panel (~4 in.^{2}).

Figure 11. Continued

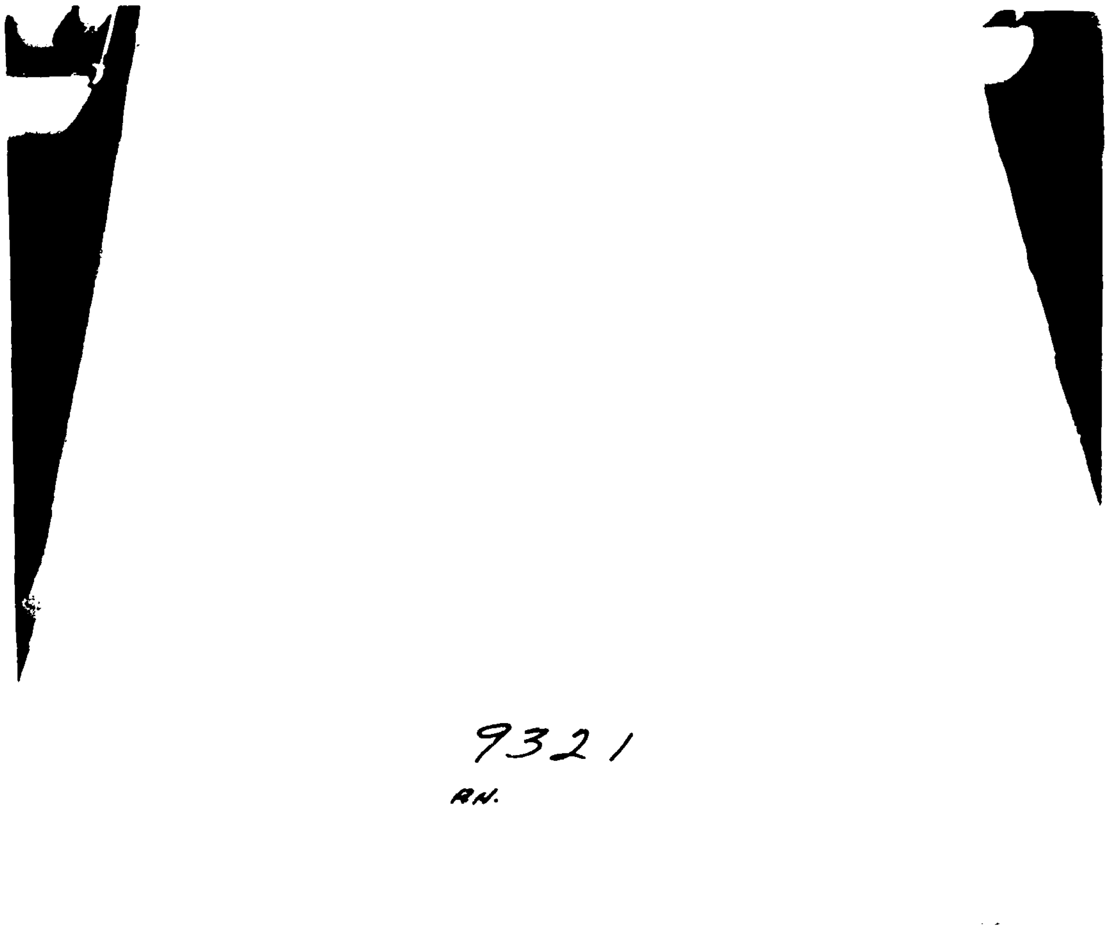


Figure 12. Deteriorated foam system maintained by sanding, priming, and coating (system 16F-1). System performing very well after weathering for 4 years.

Appendix

PRELIMINARY GUIDELINES FOR MAINTENANCE OF POLYURETHANE FOAM (PUF) ROOFING

The following guidelines (in NAVFAC specification style) are presented for maintaining PUF roofs requiring repair. This guidance is based on research on a limited number of deteriorated 2- by 4-foot PUF roofing samples reported herein and optimum procedures observed in the field and are, thus, of a preliminary nature. The procedures designated below will become established guidelines after they have been tested in full-scale field operations and found to be effective under those conditions.

1.0 Annual Preventive Maintenance

In order to obtain maximum performance from a PUF roofing system, a continuous preventive maintenance program with annual inspection and repair should be established. The annual repair should be carried out in conjunction with the annual inspection. This should consist of a thorough visual inspection of the entire PUF roofing system for overall performance and for both large and small defects in the system. A good, strong, preventive maintenance program should extend the life expectancy of the foam's protective coating system an additional 2 to 6 years before recoating is necessary.

1.1 Repair of Small Defects

Small defects in the coating or foam should be maintained during the annual inspection. This should include isolated instances of breaks in the coating attributed to cracking, flaking, or spalling, or ruptured blisters exposing the underlying foam. Minor defects can normally be repaired by cleaning all deteriorated material, dust, and dirt from the defective area and sealing with a silicone, urethane, or an acrylic caulking material dispensed from a caulking gun. The caulking material should be applied carefully so it extends beyond the defect onto the surrounding existing coating. Repair of small defects prevents them from becoming major problem areas.

1.2 Repair of Slightly Larger Areas

Inspection of a PUF roofing system will occasionally detect small, isolated areas of poor-quality foam, foam that has been mechanically damaged, or foam that is wet. Such areas that are about 1 ft^2 or larger should have the affected foam cut out and removed, and the area (including the coating) surrounding the cutout should be cleaned, allowed to dry, primed if necessary (see paragraph 2.2), and the foam replaced either with two-component canned foam or PUF or other insulation board. When the two-component canned foams are used, the edges of the foam surrounding the removed area should be beveled, cleaned, allowed to dry, and then refoamed. The void should be filled about one-half to five-eighths full of froth foam directly from the canned foam containers. Once the canned foam has been applied, it can be molded (paragraph 1.2.1) or sanded (paragraph 1.2.2) to conform to the approximate shape of the surrounding foam. The insulation board can also be sanded to conform to the surrounding foam. The repaired foam should be protected with 35 to 40 mils of the appropriate coating material or a thick coat of silicone, urethane, or acrylic caulking compound spread with a putty knife or brush. This coating or caulk should extend at least 1 inch onto the existing coating surrounding the patched area.

1.2.1 Molded Froth Foam Surface. A polyethylene-wrapped piece of plywood is placed over the void and weighted immediately after the froth foam has been introduced, and the foam is allowed to expand against and conform to the flat surface of the plywood. The foam should cure from 1 to 3 hours before coating.

1.2.2 Sanded Froth Foam Surface. The foam is allowed to rise unobstructed, and the surface is then shaped by slicing off high areas with a flat cutter and sanding flush with a power disk sander. All loose material should be removed from the surface before applying the caulking compound. The foam should cure from 1 to 3 hours before sanding and coating are attempted.

1.2.3 Insulation Board. If the roof deck is smooth rather than irregular, as with some metal decks, a patch can be made using PUF or other insulation board of the same approximate thickness as the PUF roofing system. The insulation board should be cut to the approximate size of the void in the sprayed PUF, several beads of caulk should be placed on the roof deck and around the edges of the void, and the insulation should be pressed into the caulking material. If the insulation board is thicker than the sprayed foam roof, the board surface can be sanded flush using a disk sander. The surface of the insulation board should then be sealed with a thick coat of caulking compound as specified in paragraph 1.2.

2.0 Longer Term Preventive Maintenance

All of the elastomeric coating systems used to protect PUF from the weather must be recoated periodically to obtain maximum performance from a PUF roofing system. Thus, the overall condition of the elastomeric coating system must be determined during the annual inspection. In the absence of an annual inspection and a recoating program within the proper time frame, generally 6 to 12 years, the foam roofing system may fail prematurely.

If the existing coating is weathered and shows signs of deterioration but is mostly intact and well bonded (i.e., less than 10% of the coating has spalled), the coated foam can usually be cleaned and recoated with a suitable elastomeric coating system. Any flaking or spalling of the coating is usually localized in a few areas rather than spread uniformly around the roof.

2.1 Cleaning

The roof surface should be thoroughly cleaned, preferably with a power broom or manually with a rattan or similar stiff-bristled push broom. The brooming should be sufficiently vigorous to remove all chalk, dirt, deteriorated coating, degraded foam, or other contamination. Following the brooming, all loose materials should be removed from the roof surface by vacuuming or blowing off with dry compressed air.

2.1.1 Washing. Washing of a weathered coating on a foam roof should be avoided if at all possible because of the possibility of water absorption by exposed foam. However, the silicones and certain acrylic elastomers exhibit a tackiness that tends to retain dirt and other contaminants, requiring removal by washing. If this surface contamination is not thoroughly removed, the new coating may exhibit poor adhesion to the existing weathered coating. If a thorough brooming does not remove this tenaciously held dirt and soil, the coating should be scrubbed clean with a solution of TSP in water. All of the residue should then be rinsed from the roof with clean water and all excess water removed by vacuuming or blowing off with air. The roof surface should be thoroughly dry before the recoating operation begins. Prior to any washing operation, the coating manufacturer should be contacted for specific recommendations.

2.2 Priming Before Recoating

Priming may or may not be required before recoating. This decision needs to be made on a case-by-case basis. In instances where it is difficult to determine if all adhered dirt or chalking has been removed, or if there is some doubt about the surface condition of the existing coating, the surface should be primed with a tiecoat recommended by the manufacturer of the new coating. If the existing coating is in good condition, clean with no evidence of adhered dirt or chalk, the surface need not be primed unless recommended by the manufacturer of the new coating.

2.2.1 Where small spots of the coating not exceeding about 10% of the roof area have spalled, a primer should be applied to improve the performance of the new coating system. This is effective in minimizing cracking of the new coating in surface transitions from foam to coating.

2.3 Repairs

Any defects in the coating or foam should be corrected prior to recoating in accordance with paragraphs 1.1 and 1.2.

2.4 Recoating

After the surface has been properly cleaned and repaired, it should be recoated. The coating system selected should be a high-quality elastomeric coating for foam and should be applied in at least two coats, in a "cross-hatched" manner, to give a minimum total dry film thickness of 30 mils or at the coverage recommended by the manufacturer for a new foam surface if greater than 30 mils.

3.0 Major Maintenance and Repair

If deterioration of the existing PUF roofing system is more advanced and more than 10% of the coating has spalled relatively uniformly over the entire area, thereby exposing the foam, it is usually necessary to remove all coating and deteriorated foam until a foam surface of good quality is obtained. The types of advanced coating deterioration could include flaking or spalling, excessive blistering, excessive pinholing, cracking (due either to normal coating deterioration or hailstone damage), peeling, or extensive loss of adhesion to the foam. The cleaned, exposed foam surface should be thoroughly inspected to be certain that all degraded or poor-quality foam and coating have been removed and that the remaining foam contains no wet areas. Additional foam is then applied and the new foam surface coated with a suitable elastomeric coating system.

3.1 Removal of Larger Areas of Deteriorated Foam

If a larger area (over 15 ft^2) of foam is badly degraded, of poor quality, mechanically damaged, or wet, the foam in question should be removed. The edges of the foam on the perimeter of the patch area should be beveled with a disk sander; the area should be primed, if necessary, and then refoamed; and the foam surface should be coated with a suitable elastomeric coating system. Refoaming of these larger areas should be done with regular foam spray equipment rather than the canned froth foam. Such removal and refoaming should be done in conjunction with the total maintenance of the roof (paragraphs 3.2 to 3.5).

3.2 Removal of Deteriorated Coating and Foam

If the coating is sufficiently friable, the removal of deteriorated coating and foam can be achieved using a power disk sander. Some coatings, such as the urethane elastomers, retain a degree of their original toughness and abrasion resistance even though badly deteriorated. In such cases, the deteriorated coating and foam must be removed with a modified power lawn mower, a built-up roof spudding machine, or some other suitable method of mechanical removal. Following removal, if the foam surface is excessively rough, the surface must be sanded lightly to provide a smoother substrate for application of additional sprayed PUF.

3.2.1 Sanded Foam Surface. The sanded and cleaned foam surface should not remain exposed overnight because it might absorb moisture. It is preferable to leave the newly sprayed foam exposed uncoated overnight rather than the sanded foam surface. Therefore, only that amount of deteriorated coating/foam should be scarified that can be cleaned and refoamed the same day. If the sanded foam surface must remain exposed overnight, it must be determined to be thoroughly dry by using a resistance-type moisture meter before application of additional foam is permitted.

3.3 Cleaning of Sanded Foam Surfaces

Following the sanding operation the sanded foam surface should be thoroughly cleaned to remove all dust, dirt, or debris by vacuuming or blowing off with dry compressed air. The cleaned surface should be closely inspected to determine that no foreign matter remains that might adversely affect the adhesion of the new foam to the existing sanded foam surface.

3.4 Priming Sanded Foam Surface

Priming of the cleaned, sanded foam surface before foaming, although not absolutely necessary, does enhance the adhesion of new to sanded foam. If a prime coat is recommended by the foam manufacturer, these recommendations should be followed. This generally involves the use of a light tiecoat.

3.5 Application of Additional Foam

An additional 1/2 inch or more of new PUF should be sprayed over the existing sanded foam surface. The thickness of new foam to be applied is dependent on the thickness of old (but acceptable) foam remaining and the required insulation thickness. The final foam thickness (old plus new) should be at least 1 to 1-1/2 inches.

3.6 Coating of Refoamed Surfaces

The newly foamed surfaces should be coated with a high-quality elastomeric coating system in the same manner and coverage as that recommended for a new PUF roofing system. The minimum recommended coating thickness is 30 mils dry, and the coating should be applied the same day that the foam is applied. If "same-day coating" is not possible, the new foam should be coated the following day or within 72 hours at the very latest.

3.7 Foaming Over Weathered Coating

New foam can be applied to a weathered coating of an existing foam roof in some cases. Each application must be considered on an individual basis. When considering applying new foam over a weathered coating, (1) a specialized roof moisture survey should be conducted to establish that the existing PUF roof is dry; (2) the existing PUF roofing system should be thoroughly inspected for roof defects; (3) any wet or degraded areas should be removed, the affected areas allowed to dry, and the removed areas refoamed; (4) the weathered coating surfaces should be thoroughly cleaned and primed; and (5) the new foam and quality elastomeric coating should be applied. Additional foam should not be applied over an impermeable coating or over a silicone-coated foam roof.

4.0 Complete Removal of Foam Roof Versus Major Maintenance

In the case of advanced foam roof deterioration, it may be necessary to remove the foam completely from the substrate in preparation for reroofing. Before the decision for complete removal and reroofing is made, however, the existing PUF roof should be thoroughly examined to determine the full extent of deterioration. It is possible that a sufficient quantity of acceptable-quality foam remains to make it economically feasible to remove only the degraded portion and refoam as described in paragraph 3.7. If this is the case, it should be determined that the existing good foam is not wet before a final decision is made. This assessment can best be made with a nuclear moisture meter survey of the roof.

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